Original Article

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A Comparison of Vocal Function between Females with Benign Vocal Fold Lesions and Females with Normal Voices by Use of Electroglottograph

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Abstract:

Objective: To compare vocal function between females with benign vocal fold lesions, and females with normal voices by use of electroglottograph (EGG), also in addition to determining which EGG parameters were significantly correlated with the perceptual degree of dysphonia.

Material and Methods: EGG data were obtained from 32 females with benign vocal fold lesions and 32 females with normal voices. The EGG parameter values were analyzed from their productions of four sustained vowels (/a:/, /u:/, /i:/, and /æ:/).

Results: The two perturbation measures of EGG signals, EGG-jitter and EGG-shimmer of females with benign vocal fold lesions were significantly higher than those of normal females at a p-value<0.01 for all four vowels. EGG-SDF0 of females with benign vocal fold lesions were significantly higher than those of normal females at a p-value<0.01 for /i:/, and /æ:/. EGG-F0 of females with benign vocal fold lesions were significantly lower than those of normal females at a p-value<0.01 for /u:/, /i:/, and /æ:/. The differences in contact quotient were non-significant on all four sustained vowels between the two groups. In addition, EGG-SDF0 was found to be significantly correlated with the perceptual degree of dysphonia for four sustained vowels.

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Conclusion: The results of this study showed the differences between vocal function of females with benign vocal lesions and females with normal voices, using EGG parameters. Furthermore, EGG-SDF0 could be used as an indicator for the degree of severity of dysphonia in females with benign vocal fold lesions.

Keywords: benign vocal fold lesions, electroglottograph, vocal function

Introduction

The most common cause of voice disorders is benign vocal fold lesions.[1,2] Benign vocal fold lesions are unusual growths of tissues on the vocal folds that are not malignant. These lesions include; vocal nodules, vocal polyps, vocal cysts, and Reinke's edema. Almost all types of benign vocal fold lesions developed from vocal abuse; caused by injury to and changes in the mucosal layer or muscle tissues of the vocal folds.[3-7] These lesions will affect the mass, size, and glottal closure pattern of the vocal folds. In consequence, voice quality, pitch and loudness are deviated from normal voice.[8]

Electroglottograph (EGG) is a common instrument that has been used to evaluate the vocal vibration in patients with voice disorders. An EGG is an indirect method used to evaluate the movement, and closure pattern of the vocal folds. This method is simple to use as well as being non-invasive.[7,9,10] EGG makes use of the principle of the electrical conductivity of human tissues. Body tissues are a good electrical conductor; whereas air is a poor conductor. During vibration of the vocal folds, the impedance is increased when the vocal folds are opened. On the other hand, the impedance is decreased when the vocal folds are closed.[10,11] These patterns of increase and decrease of the impedance during vocal vibration are shown in the EGG waveform (Figure 1). Furthermore, an EGG also exhibits parameter values, such as contact quotient (CQ), fundamental frequency (EGG-F0), frequency/amplitude perturbation (EGG-jitter or EGG-shimmer) and so forth.[10-12]

In research pertaining to the function of vocal folds by using an EGG, there have been many studies which evaluated the vibratory patterns of the vocal folds; in both normal voice and voice disorders, with or without pathologies. Some studies compared the degree of vocal fold contact between a vocal nodules group and a normal group. The results of these studies reported that: the

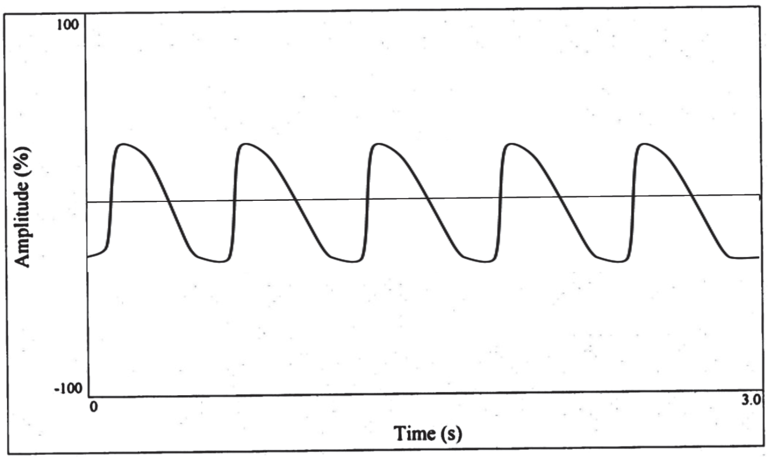

Figure 1 Electroglottographic waveform of sustained vowel /a:/ in normal voice[13]

degree of vocal fold contact were significantly lower for participants with benign vocal fold lesions compared to participants with normal voice.[14,15] On the other hand, the study of Lim et al. reported that: the degree of vocal fold contact were significantly higher for participants with Reinke's edema compared to participants with normal voice.[16] They also concluded that some EGG parameters showed significant differences between participants with Reinke's edema and the participants with normal voice. In addition, Hosokawa et al. concluded that there were nonsignificant degrees of vocal fold contact between participants with muscle tension dysphonia and participants with normal voice. They also reported that the perturbation parameters of EGG were shown to be significantly high in participants with muscle tension dysphonia.[17]

However, prior studies on vocal fold vibrations of patients with benign vocal lesions by use of EGG are limited. The purposes of this study were to compare the measures of vocal function between the two groups, by using EGG, and also to determine which EGG parameters were significantly correlated with the perceptual degree of dysphonia. The results of this study may help to clarify the differences in vocal function between vocal folds with and without benign lesions. Furthermore, the EGG parameters which are significantly different between the two groups, may be used to monitor the progression of voice therapy in patients with benign vocal fold lesions.

Material and Methods

Ethical approval for the present study was obtained from the Ethical Clearance Committee of the Faculty of Medicine, Ramathibodi Hospital, Mahidol University (ID 07-59-26). All participants were informed of its purposes and the procedures of this study. Participants were asked for their permission to participate in this study, and they all signed a consent form.

This cross-sectional study was conducted with participants who were enrolled between; August, 2016-June, 2017, at the Speech Clinic of Ramathibodi Hospital. A total of 64 participants participated in this study, and were divided equally into two groups, the experimental group and the control group.

The experimental group consisted of 32 females with benign vocal folds lesions. The mean age of this group was 51.03 years [standard deviation (S.D.)=9.64, age range 25-65 years]. All participants in this group had hoarseness. They were examined and diagnosed by otolaryngologists as having benign vocal folds lesions, without laryngeal nerve paralysis as follows: 14 females with bilateral vocal nodules, 1 female with bilateral vocal cysts, 3 females with a single vocal nodule, 9 females with a single vocal cyst, 4 females with a vocal polyp and 1 female with a hemorrhagic mass on left vocal fold. Furthermore 18 out of the 32 participants (56.2%) in this group were noted as having small sized vocal nodules or cysts. For the rest of the participants in the experimental group the information of nodule or cyst size could not be found. Participants of this group, who could not be evaluated with EGG because of severe dysphonia and/or participants who could not sustain vowels for at least 3 seconds, were excluded from this study.

The control group consisted of 32 females with normal voice, with a mean age of 49.60 years (S.D.= 11.65, age range 25-65 years). The researcher evaluated the voice quality of participants in the control group by having a conversation with each of them; in which they would produce normal pitch, loudness, and/or quality of voice. Participants of the control group who had a common cold and/or sore throat did not participate in this study. Furthermore, all participants in the control group were evaluated with EGG. If EGG waveforms and EGG parameters values of the control group participants were abnormal, the participants would be excluded from the study.

The demographic characteristics of the participants in both groups are presented in Table 1.

Table 1 Demographic characteristics of the participants

Group	Characteristics	Values
Control (n=32)	Gender (female)	32
	Age (years)	49.60±11.65
	Age range (min–max)	25–65
Experimental (n=32)	Gender (female)	32
	Age (years)	51.03±9.64
	Age range (min–max)	25–65
	Bilateral vocal nodules	14
	Bilateral vocal cysts	1
	A single nodule	3
	A single vocal cyst	9
	A vocal polyp	4
	A hemorrhagic mass on left vocal fold	1

Electroglottograph, model YEM made by Tiger DRS, Inc., was used in this study. There were two electrodes, 32 mm in diameter, for measuring the amount of electrical current between the electrodes. The output signals, EGG waveform and EGG parameters, were displayed and analyzed by using a Vocal Assessment software program. EGG parameters and their descriptions derived from electroglottographic signals are presented in Table 2.

For evaluating perceptual degree of dysphonia, the GIRBAS scale[18] was used. All items on the GIRBAS scale are described as follows: Grade of severity (G) represents the overall degree of hoarseness; Instability (I) corresponds to the fluctuation in pitch and/or voice quality over time; Roughness (R) corresponds to the perception of the irregularity of vocal fold vibration; Breathiness (B) corresponds to the perception of air leakage through the glottis or air in the voice; Asthenia (A) corresponds to a weakness or lack of power in the voice; Strain (S) corresponds to an impression of hyperfunction during phonation.[7,18,19] All items on the GIRBAS scale were rated by using a four-point rating scale ranging from 0–3 as follows: normal=0, slight disturbance=1, moderate disturbance=2, and severe disturbance=3.[7,19]

All participants were asked to provide their medical history, and then assessed the vocal function by use of EGG. The evaluation was conducted in a quiet room. The participants' skin, where the electrodes were placed, was cleaned with alcohol and a skin preparation gel;

Table 2 Parameters of electroglottography and the description

Parameters	Abbreviation	Description
Contact quotient	CQ	A measure of the degree of vocal fold approximation during phonation (represents values in percentages).[10]
Fundamental frequency	EGG-F0	A measure of the rate of quasi-periodic vibration of the vocal folds. This parameter was expressed in Hertz.[6,10]
Standard deviation of fundamental frequency	EGG-SDF0	A measure of frequency variability, which reflects the variation in fundamental frequency during a long time period of speech production; such as sustaining a vowel or in oral reading. This parameter was expressed in Hertz.[6,7,10]
Frequency perturbation	EGG-jitter	The short-term perturbation of the fundamental frequency in the EGG signals (represents values in percentages).[10]
Amplitude perturbation	EGG-shimmer	The short-term perturbation of the amplitude in the EGG signals (represents values in percentages).[10]

CQ=contact quotient, EGG-F0=fundamental frequency, EGG-SDF0=standard deviation of fundamental frequency, EGG-jitter=frequency perturbation, EGG-shimmer=amplitude perturbation then two electrodes with electrode gel were placed on the thyroid laminae and at the same level as the glottis.

(a) For the experimental group, EGG measurement were conducted for assessing vocal function. The participants in this group were instructed to sustain four vowels (/a:/ /u:/ /i:/ /æ:/) at a comfortable pitch and loudness level. Each vowel was continuously enunciated three times, and each time it had to be prolonged for at least 3 seconds. The whole period of EGG measurement was around 5-8 minutes, and the interval between each sustained vowels for analyzing the signals were around 20-25 sec. After that, the participants in this group read the standard Thai passage. There are 100 syllables with all Thai consonant sounds in this passage[20] While participants sustained vowels for EGG measurement, and read the passage all speech samples were recorded on video. The reading passage, as speech samples, were recorded for perceptual voice quality evaluation, because only sustained vowels might not provide enough information for the perceptual evaluation. The reading speech samples were not used in EGG measurements, because the EGG could only measure a sustained vowel. After collecting data of all participants in the experimental group, three experienced speech-language pathologists rated the perceptual degree of dysphonia of participants in this group, by using the GIRBAS scale.[18] These speech-language pathologists had at least 20 years of professional experience in the area of speech and voice disorders. They separately rated the voice quality by watching video recording of speech samples at the same time.

(b) For the control group, the participants were required to sustain four vowels (/a:/ /u:/ /i:/ /æ:/) for EGG measurement, in the same way as the experimental group. The sustained vowels of participants in the control group were not rated by the GIRBAS scale. However, EGG parameter values and EGG waveform amplitudes of participants in the control group had to be normal.

The data of this study were analyzed using IBM Statistical Package for the Social Science for Windows, Version 24.0. Mean and standard deviations were used to describe the EGG parameter values. A Mann-Whitney U Test was performed to evaluate the mean differences of EGG parameters between the two groups. Differences were considered significant with a p-value<0.05. Moreover, the correlation between the EGG parameters and the overall degree of dysphonia or G from the GIRBAS scale of the experimental group was determined using Spearman's rank correlation.

Results

Comparison of EGG parameters between the experimental group and the control group.

The mean values of both EGG-jitter and EGG-shimmer of the experimental group were significantly higher than the control group: p-value<0.01 for /a:/, /u:/, /i:/, and /æ:/. Indicating that the mean values of EGG-SDF0 of the experimental group were significantly higher than the control group: p-value<0.01 for /i:/, and /æ:/. The mean values of EGG-F0 of the experimental group were also significantly lower than those of the control group; p-value<0.01 for /u:/, /i:/, and /æ:/. However, there were nonsignificant differences between the two groups in the mean values of EGG-F0 and EGG-SDF0 for /a:/, and the mean values of EGG-SDF0 for /u:/. Moreover, the differences in the mean CQ values of all four vowels, between the experimental and the control group, were nonsignificant (Table 3).

EGG parameters of the experimental group that were significantly correlated with the overall degree of dysphonia or G from the GIRBAS scale.

Three experienced speech-language pathologists rated the overall degree of dysphonia or G from the GIRBAS scale of participants in the experimental group as a moderate degree of dysphonia.

Table 3 Comparison of parameters of electroglottography for four vowels between the control group and the experimental group

EGG parameters	Vowels	Groups	Mean	S.D.	95% Confidence Interval	U	Z	p-value
EGG-F0 (Hz)	/a:/	control	215.94	28.71	205.58-226.29	366.00	-1.96	0.05
		experimental	203.31	27.80	193.29-213.34			
	/u:/	control	232.08	28.82	221.69-242.47	287.00	-3.02*	0.00
		experimental	208.95	28.36	198.72-207.82			
	/i:/	control	235.93	28.87	225.52-246.34	282.00	-3.09*	0.00
		experimental	212.53	28.36	202.31-222.76			
	/æ:/	control	226.47	27.59	216.52-236.42	286.00	-3.04*	0.00
		experimental	204.96	27.98	194.87-215.05			
EGG-SDF0 (Hz)	/a:/	control	2.88	1.26	2.42-3.33	390.00	-1.64	0.10
		experimental	3.76	2.17	2.97-4.54			
	/u:/	control	2.55	0.89	2.23-2.87	420.00	-1.21	0.22
		experimental	3.53	2.54	2.62-4.45			
	/i:/	control	1.50	1.08	1.11-1.89	120.00	-5.26*	0.00
		experimental	3.80	2.08	3.05-4.55			
	/æ:/	control	2.42	0.86	2.11-2.74	225.50	-3.85*	0.00
		experimental	4.04	2.03	3.31-4.78			
EGG-jitter (%)	/a:/	control	0.38	0.21	0.29-0.45	270.00	-3.25*	0.00
		experimental	0.79	0.62	0.56-1.01			
	/u:/	control	0.31	0.27	0.22-0.41	244.00	-3.59*	0.00
		experimental	0.64	0.75	0.37-0.91			
	/i:/	control	0.33	0.20	0.26-0.41	215.50	-3.98*	0.00
		experimental	0.84	0.86	0.53-1.16			
	/æ:/	control	0.35	0.17	0.29-0.42	153.50	-4.81*	0.00
		experimental	0.98	0.81	0.69-1.27			
EGG-shimmer (%)	/a:/	control	1.71	1.30	1.24-2.18	266.50	-3.29*	0.00
		experimental	3.58	2.52	2.67-4.48			
	/u:/	control	1.20	1.20	0.77-1.64	200.50	-4.18*	0.00
		experimental	2.67	2.06	1.92-3.41			
	/i:/	control	1.50	1.08	1.11-1.89	231.50	-3.77*	0.00
		experimental	3.50	2.82	2.48-4.52			
	/æ:/	control	1.70	1.12	1.29-2.11	169.50	-4.59*	0.00
		experimental	4.31	2.67	3.35-5.28			
CQ (%)	/a:/	control	71.08	4.95	69.29-72.87	449.00	-0.85	0.39
		experimental	71.99	5.45	70.03-73.96			
	/u:/	control	68.27	5.96	66.12-70.42	416.00	-1.29	0.19
		experimental	70.32	3.93	68.89-71.73			
	/i:/	control	67.85	7.31	65.21-70.49	465.00	-0.63	0.53
		experimental	69.34	4.15	67.85-70.84			
	/æ:/	control	70.17	6.68	67.76-72.58	481.50	-0.41	0.68
		experimental	71.26	5.23	69.37-73.14			

*Significant at p-value<0.01, control group N=32, experimental group N=32, U=Mann-Whitney U, Z=Z-score, S.D.=standard deviation, EGG=electroglottography, EGG-F0=fundamental frequency, EGG-SDF0=standard deviation of fundamental frequency, EGG-jitter=frequency perturbation, EGG-shimmer=amplitude perturbation, CQ=contact quotient

The results from the Spearman's rank correlation showed that only EGG-SDF0 was significantly correlated with the overall degree of dysphonia for all four vowels. The Spearman correlation coefficients for the four vowels were: /a:/: r_s=0.47, p-value=0.01, /u:/: r_s=0.43, p-value=0.01, /i:/: r_s=0.53, p-value=0.00, /æ:/: r_s=0.47, p-value=0.01. The correlation coefficients for all four vowels revealed a moderate positive correlation[21] between the overall degrees of dysphonia, and EGG-SDF0 values of the four vowels.

Discussion

In this present study, EGG parameters were computed using data from females with normal voice and females with benign vocal folds lesions. The results of this present study showed that the EGG parameter values of both groups were significantly different.

The results demonstrated that the two perturbation measures of electroglottographic signals, EGG-jitter and EGG-shimmer, of females with benign vocal fold lesions were significantly higher than those of normal females for all four vowels. The values of EGG-SDF0 of females with benign vocal fold lesions were significantly higher than those of normal females for /i:/, and /æ:/. According to the physiology of the normal vibration of vocal folds, the mass and stiffness of the vocal folds are important factors that directly affected the vibratory pattern of the vocal folds.[3,4,6,7,22,23] When the vocal folds were changed, such as by an increase in the vocal mass or a decrease in the elasticity of the cover of the vocal folds, the normal vibration of vocal folds is disrupted. These factors cause an irregularity in the vocal fold vibration, and a disturbance of normal vibratory patterns of the vocal folds.[3,4,6,7,23] EGG waveforms with an irregularity of vocal fold vibration would be an irregular waveform, and higher values of EGG-SDF0, EGG-jitter, and EGG-shimmer would then be produced.[11,24,25] Therefore, in this present study, the relatively high values of EGG-SDF0, EGG-jitter, and EGG-shimmer of females in the benign vocal fold lesions group were related to the irregularity of the vocal fold vibration as a result of increased vocal mass and/or stiffness of the vocal folds. On the other hand, the values of EGG-SDF0, EGG-jitter, and EGG-shimmer of females with normal voice were lower because of appropriate mass, and no irregularity of vocal fold vibration. These significantly high values of EGG-SDF0, EGG-jitter and EGG-shimmer of females with benign vocal fold lesions, within our study, were similar to those of prior studies that used EGG to evaluate the vocal function of participants with hyperfunctional voice disorders compared with participants having a normal voice. For example, Lim et al.[16] reported that: the SDF0, jitter and shimmer from EGG were significantly higher in females with Reinke's edema compared to females with normal voice.Similar to the results of Hosokawa et al., in which they reported that: the perturbation parameters from EGG signals were obviously higher for participants with muscle tension dysphonia and organic voice disorders than those of participants with normal voice.[17]

For EGG-F0, which was related to the frequency of vocal vibration, if important factors, such as mass, tension, thickness and length of the vocal folds were altered the frequency of vocal vibration was changed. Lesions such as nodules would enlarge the vocal folds, thus the vocal folds vibrated at a lower, average frequency; resulting in a low value of F0.[3,6,7,10,22,23,26] Therefore, the lower values of EGG-F0 of all four vowels of females with benign lesions in this study were related to enlarged vocal folds, which in turn caused the average frequency to be low. Contrary to this, the values of EGG-F0 of females with normal voice were higher, due to this group having a normal vocal fold structure. The significantly low value of EGG-F0 of females with benign vocal fold lesions in this study was in agreement with prior studies, such as Lim et al.[16] and Hosokawa et al.[17]

Regarding the results of the present study, there were some parameters, such as EGG-F0 and EGG-SDF0 of /a:/ and EGG-SDF0 of /u:/, which were not significantly different between the two groups. Speakers with a vocal nodule might have had a wide range of severity, which depended on the size of the mass as well as degree of dysphonia. Some speakers with vocal nodules may produce high values of jitter and shimmer, but they might also produce normal values of F0, which were not different from those speakers with normal voice.[15] Depending on the size of the benign mass and the stiffness of the vocal folds, a small nodule might not change the frequency of vocal fold vibration.[15] Eighteen out of 32 (56.2%) females with benign vocal fold lesions, who participated in this study, were noted as having had a small sized vocal nodule or cyst. Accordingly, this might be the reason as to why the EGG-F0 and EGG-SDF0 of /a:/ and EGG-SDF0 of /u:/ were not significantly different between the two groups, in this present study.

A comparison of CQ showed that the CQ values of all four vowels were not significantly different between the two groups. Based on the review of related literature, high CQ values indicated laryngeal hyperfunction, and it was reported that the CQ values increased along with the area of vocal fold contact.[6,7,11,12,25,27-29] In addition, the size of a vocal mass was related to laryngeal hyperfunction, which meant that speakers with a larger vocal mass were more likely to have laryngeal hyperfunction.[30] Most females with benign vocal fold lesions (56.2%), in this study, were known to have a small sized vocal nodule and/or cyst. Therefore, a small mass in most females with benign vocal fold lesions might be indicative to a small degree of laryngeal hyperfunction, additionally it might be the reason why the CQ values of females with benign vocal fold lesions were not significantly different compared to females with normal voice. This finding agreed with that of Hosokawa et al.[17] They reported nonsignificant differences in CQ values between participants with muscle tension dysphonia and participants with normal voice. However, the CQ values between the benign mass group and the normal group, in this present study, showed that they were inconsistent with some prior studies. The study of Dejonckere and Lebacq, and the study of Hall reported that: the vocal fold contact of participants with vocal nodules were significantly lower compared to those of normal participants.[14,15] They concluded that hyperfunctional voice disorders caused vocal fatigue, and might result in a posterior glottal chink.[15] Therefore, the vocal fold contact during the phonation of participants with vocal nodules was reduced, resulting in lower values of the degree of vocal fold contact when compared to the normal participants.[14,15] Furthermore, the results of this present study were not consistent with the result of Lim et al.[16] A possible explanation was that the participants in this present study were different from those in the study of Lim et al.[16] The participants in the study of Lim et al. had Reinke's edema. Reinke's edema is an increased vocal mass along the vocal folds. While a nodule or cyst often occurred at the anterior one-third of the vocal folds and was the size of a nodule or cyst smaller than Reinke's edema.[6,7] A large size of the vocal folds was attributed to a more severe laryngeal hyperfunction, and in effect to a higher CQ value.[6,7,30] Therefore the results of Lim et al., the CQ values of Reinke's edema group were significantly higher than those of the normal group, which were not consistent to the results of this current study. In this study, most participants of the experimental group had nodules or cysts, which were smaller than Reinke's edema. In consequence, the CQ values of benign lesions group in this present study were not significantly high, when compared to the normal group. Although, there were non-significant differences in CQ values between the two groups in this present study, the CQ values tended to be higher for females with benign vocal fold lesions.

Therefore, the relatively high CQ values in the present study might indicate that females with benign vocal fold lesions were likely to have a higher degree of laryngeal hyperfunction than females with normal voice.

Moreover, within this study, the EGG-SDF0 parameter was found to be significantly correlated with the perceptual overall degree of dysphonia or G from the GIRBAS scale, for all four vowels, and the correlation coefficients were moderately positive. This meant that when one value increased or decreased, the other value increased or decreased as well.[21] The standard deviation of the fundamental frequency (SDF0), or frequency variability that corresponded to the stability of the vibration of the vocal folds, indicated the regularity of vocal vibration.[7,31-33] Furthermore, the higher values of SDF0 were reported to be directly related with the perception of an aperiodic component in voice quality, such as roughness and instability.[32,33] In this current study, the EGG-SDF0 values of females with benign vocal fold lesions were higher than those of females with normal voice. The higher values of EGG-SDF0 indicated instability in vocal fold vibration, and affected the degree of irregularity of vocal fold vibration. When the vocal folds vibrated irregularly, as the result of a benign mass on the vocal folds, listeners might perceive a more aperiodic component in the voice quality; resulting in the perception of a higher degree of dysphonia.[7,32,33] Therefore, the results of this present study indicated that EGG-SDF0 might be a sensitive EGG parameter that may be correlated with the perceptual overall degree of dysphonia in females with benign vocal fold lesions.

However, there were some limitations within this study. The participants of the control group were not examined by an otolaryngologist; therefore, it may be possible that some participants may have lesions in the vocal folds. The size of vocal lesions of participants in the experimental group should be considered for future study.

Conclusion

The results of this study showed that the vocal function of females with benign vocal fold lesions was different from females with normal voice by using EGG parameters. In addition, EGG-SDF0 was found to be significantly correlated with the overall degree of dysphonia for all four sustained vowels. Accordingly, EGG-SDF0 could be used to monitor the progress of voice therapy, and also used as an indicator of the degree of severity of dysphonia for females with benign vocal fold lesions. An EGG is an objective tool that should be used along with perceptual assessment as the gold standard for voice evaluation.

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Conflict of interest

There is no conflict of interest in this article.

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