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Electroglottographic Measurements of Glottal Function in Voice according to Gender and Age

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ABSTRACT

Electroglottography (EGG) is a common method for providing non-invasive measurements of glottal activity. EGG has been used in vocal pathology as a clinical or research tool to measure vocal fold contact. This paper presents the results of pitch, jitter, and closed quotient (CQ) measurements in electroglottographic signals of young (mean = 22.7 years) and elderly (mean = 74.3 years) male and female subjects. The sustained corner vowels /i/, /a/, and /u/ were measured at around 70 dB SPL since the most notable among EGG variables is the phonation intensity, which showed positive correlation with closed phase. The aim of this paper was to measure EGG data according to age and gender.

In CQ, there was a significant difference between young and elderly female subjects while there was no significant difference between young and elderly male subjects. The mean value for young males was higher than that for elderly males while the mean value for young females was lower than that for elderly females. Thus, it can be said that in mean values, increased CQ was related to decreased age for females, while CQ decreased for males as the speaker's age decreased. Although the laryngeal degeneration due to increased age seems to occur to a lesser extent in females, the significant increase of CQ in elderly female voices could not be explained in terms of age-related physiological changes. In standard deviation of pitch and jitter, the mean values for young and elderly males were higher than that for young and elderly females. That is, male subjects showed higher in mean values of voice variables than female subjects. This result could be considered as a sign of vocal instability in males.

It was suggested that these results may provide powerful insights into the control and regulation of normal phonation and into the detection and characterization of pathology.

Keywords: EGG, pitch, jitter, closed quotient, voice disorder, vocal instability, vocal pathology

1. Introduction

During phonation, the vocal folds open and close as a result of several laryngeal and extralaryngeal activities. The phases of closure and opening of the vocal folds follow one another at a rate defined by the fundamental frequency (Fo).

Traditionally, the vocal fold examination is performed with laryngeal mirror since the mid 19th century. Stroboscopy was one of the first methods used to study the vocal fold vibrations. The stroboscopic image may provide a relatively accurate picture for regular vibratory patterns. However, the validity of the strobe image may be questionable when there is irregular vibration. Glottographic techniques have been used to reflect the vibratory movements of the vocal fold during phonation in speech research laboratories since 1950s.

Ultra-high-speed films are most commonly used to monitor details of the glottal cycle. That is, Ultra-high-speed filming of the vocal folds during phonation has been used for filmed glottal activity at speed of 3,000 to 8,000 frames per second. But this technique has some disadvantages in terms of expense and relative complexity. It is therefore desirable to use glottographic techniques such as photoglottography (PGG) and

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electroglottography (EGG) in place of this more difficult and more invasive technique.

PGG technique is based on measurement of the intensity of light introduced supraglottally that reaches a photosensor placed on the neck below the level of vocal folds. PGG involves directing a light source toward the glottis from above or below and monitoring its intensity on the other side, to measure glottal width. This technique has proven extremely useful for studying the coordination of glottal movements with those of the suprasegmental articulators. For studies of phonation it may supply measures of opening and closing time during the glottal cycle which may be clinically or pedagogically useful. It may also be useful for monitoring glottal activity preparatory to phonation or its initiation. However, this approach also has some question about its reliability and validity. PGG does not provide absolute values for glottic area, and it may be affected by factors such as movement of the light source in relation to the glottis.

EGG, also sometimes called Laryngography, is a non-invasive method, based on Ohm's law, of evaluating vocal fold function. Originally developed by Fabre in 1956 and refined in 1974 by Adrian Fourcin. EGG measures the variation in electrical resistance between 2 electrodes placed on each side of the thyroid cartilage (Titze, 1990; Baken, 1992; Ferrand, 2009). EGG reflects the cross-sectional area and three dimensional configuration of glottis related to its opening and closing. The vocal fold contact yields a glottal waveform called glottogram. As the glottis opens and closes during phonation, the impedance to the current passing from one electrode to the other changes in proportion to the contact area of the vocal folds. While the folds are apart, the current paths between the electrodes are fewer and longer than when the folds are in contact. As the folds approximate, more current passes through the larger contact area. The waveform what we call Lx waveform or EGG waveform representing this changing signal over time can give valuable information about the closing and closed phases of the glottal cycle (Dromey et al., 1992).

In general, the EGG and PGG signals provide information about complementary parts of the glottal cycle - PGG about the open period and EGG about the closed period. However, it is evident that the glottis rarely either opens or closes abruptly over its entire length. Rather, for part of the cycle, the folds are likely to be in contact or separated over only part of their length. It was found that glottographic signals such as PGG and EGG appear to be capable of supplying much of the significant information available in Ultra-High-Speed films (Baer et al., 1983; Childers & Krishnamurthy, 1985; Kania et al., 2004; Baken, 1992).

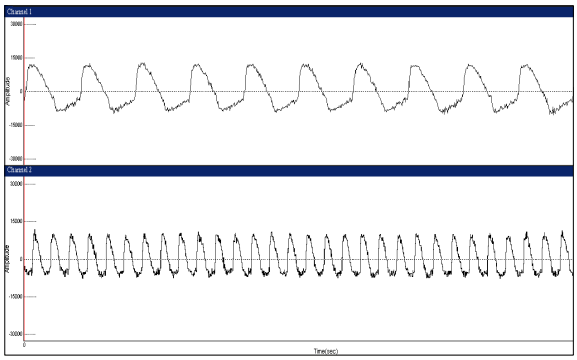

Figure 1. Lx waveform: male (upper) vs. female (lower) in 0.1 second

The glottal closed quotient (CQ) is the fraction of time the glottis is considered closed and has been thought to be a good indicator of voice quality.

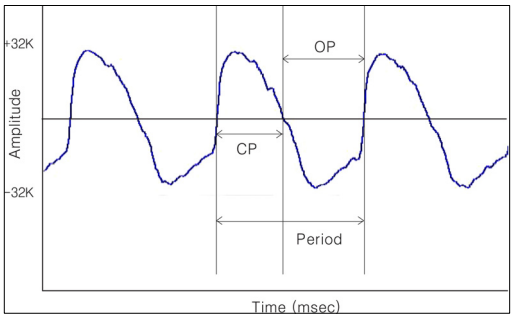

Figure 2. Closed phase (CP) and open phase (OP)

As shown in Figure 2, a period (P) or duty cycle consisted of closed phase (CP) and open phase (OP) in 50% AC flow. Closed quotient (CQ) is defined as CP divided by P.

In closed phase, the vocal folds are in full contact, preventing air from passing through the glottis. The slight increase and decrease observed in the signal could be due to the elastic collision of tissue.

The most prominent examples of parameters may be CQ and closed-to-open ratio. CQ can be found by comparing vibratory periodicity with closed phase. Since CQ represents the ratio of the time taken for the vocal folds to make contact with their surroundings, high levels of it will increase the duration of the closure. Similarly, low levels of CQ will decrease the duration of closure (Orikoff, 1991).

2. Method

2.1 Subjects

Two different age and gender groups of normal subjects participated in this study. One group was 100 young normal subjects with 50 males and 50 females between the ages of 21 to 27 years (mean = 22.7). And the other group was 60 elderly normal subjects with 30 males and 30 females between the ages of 70 to 81 years (mean = 74.3). None reported any history of voice training or vocal, speech, or auditory pathology. All were apparently free of any respiratory or phonatory symptoms at the time of testing.

2.2 Recordings

For the EGG data, Electroglottography (KAY Elematrics, model 6103) was used in this experiment. Each subject, seated in a quiet room, was asked to produce the sustained vowels with "comfortable" modal register voice. Sustained phonation is a standard method of voice assessment (Colton & Casper, 1996). Each vowel prolongation was maintained at around 70 dB SPL because the ratio of vibratory periodicity differs due to the intensity of tone. When the intensity of tone is low, the closed phase grows longer than open phase, and the closed contact increases along with the closed quotient (Gaze et al., 1990; Orlikoff & Kahane, 1991).

2.3 Measurements

In this experiment, the three corner vowels (i.e., /a/, /u/ and /i/) were measured in order to see if the mean value of each parameter can be affected by different vowels. CQ is the highest in /u/ among three corner vowels with the same intensity and pitch, but there were no significant differences. However, it was found that there were no significant differences among three different vowels. Thus, the mean value of the three vowels will be used throughout this paper.

2.4 Statistical Analysis

Statistical comparisons between young and elderly groups were made by two-sample t test for independent samples with equal variances. Since the number of subjects in two groups were more than 30 (i.e. n>30), respectively, two-sample t test can be performed based on the Central Limit Theorem. Significant level was set on p<.001.

3. Results

The results are summarized in Table 1 and Table 2.

Table 1. T-test results of young male (M) and female (F) subjects

	gender	N	mean	SD	t
pitch	M	50	121.96	12.73	-19.243***
	F	50	219.99	8.83	
jitter	M	50	.483	.103	-0.048
	F	50	.326	.075	
CQ	M	50	50.36	5.31	0.041
	F	50	48.38	3.71	

*** p<.001

For 100 young subjects (50 males and 50 females), the mean values of parameters including (a) pitch (b) jitter and (c) CQ are shown in Table 1.

In pitch, the mean value was 121.96 Hz for males and 219.99 Hz for females. In jitter as well as CQ, there was no significant difference between young male and female subjects.

Table 2. T-test results of elderly male (M) and female (F) subjects

	gender	N	mean	SD	t
pitch	M	30	139.54	5.56	-17.354***
	F	30	183.10	7.09	
jitter	M	30	.948	.286	-0.462
	F	30	.715	.172	
CQ	M	30	47.91	3.22	-0.034
	F	30	51.77	2.10	

*** p<.001

For 60 elderly subjects (30 males and 30 females), the mean values of the four parameters are shown in Table 2.

In pitch, the mean value was 139.54 Hz for males and 183.10 Hz for females. In jitter, there was no gender difference between elderly male and female subjects. Between young and elderly male subjects, there was no gender difference in CQ.

Table 3. T-test results of young and elderly male subjects

	gender	N	mean	SD	t
pitch	young	50	121.96	12.73	-11.752***
	elderly	30	139.54	5.56	
jitter	young	50	.483	.103	-7.192***
	elderly	30	.948	.286	
CQ	young	50	50.36	5.31	15.956
	elderly	30	47.91	3.22	

*** p<.001

Figure 3 through Figure 5, we can compares the mean values of parameters between young and elderly male subjects.

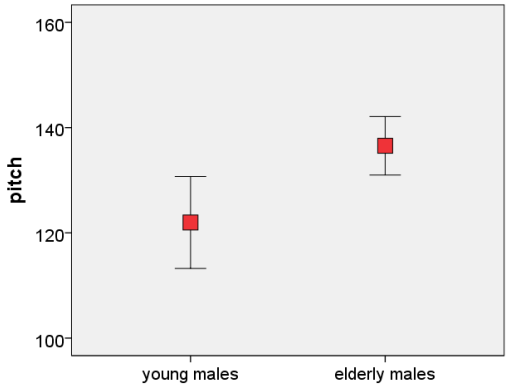

Figure 3. Pitch between young and elderly males

In pitch, the mean value shows 121.96 Hz (SD: 12.73) for young males and 139.54 Hz (SD: 5.56) for elderly males. It is found that there is a significant difference of pitch between the two groups.

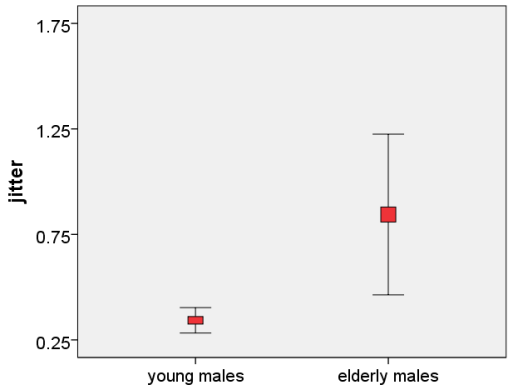

Figure 4. Jitter between young and elderly males

In jitter, the mean value shows .483% (SD: .103) for young males and .948% (SD: .286) for elderly males. There is a significant difference between the two groups within the range of normal threshold.

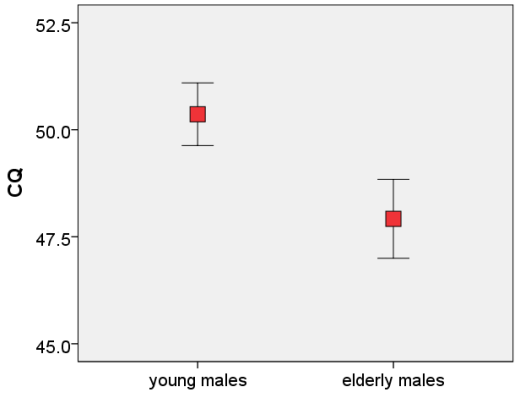

Figure 5. CQ between young and elderly males

In CQ, the mean value shows 50.36% (SD: 5.31) for young males and 47.91% (SD: 3.22) for elderly males. There is a significant difference between the two groups.

Table 4. T-test results of young and elderly female subjects

	gender	N	mean	SD	t
pitch	young	50	219.99	8.83	14.056***
	elderly	30	183.10	7.09	
jitter	young	50	.347	.059	-18.536***
	elderly	30	.917	.356	
CQ	young	50	48.39	.771	-21.251***
	elderly	30	51.78	.710	

*** p<.001

Figure 6 through Figure 8, we can also compares the mean values of parameters between young and elderly male subjects.

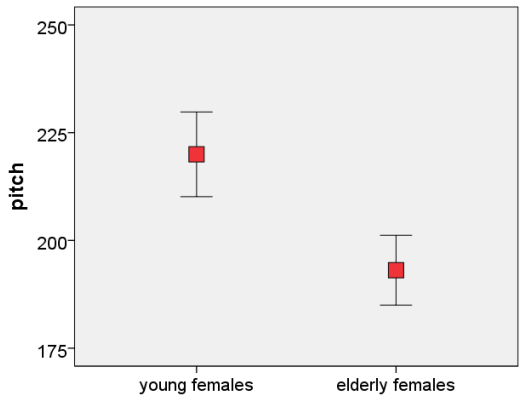

Figure 6. Pitch between young and elderly females

In pitch, the mean value is 219.99 Hz (SD: 8.83) for young females and 183.10 Hz (SD: 7.09) for elderly females. There is a significant difference between the two groups.

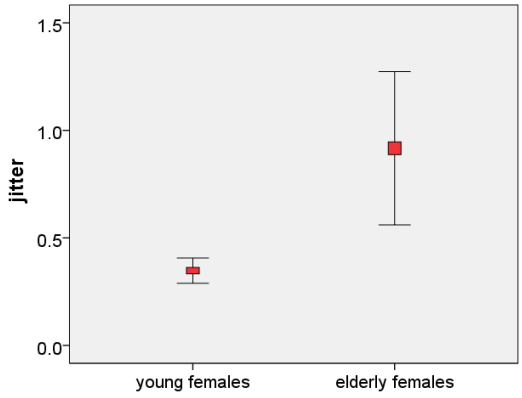

Figure 7. Jitter between young and elderly females

In jitter, the mean value is .326 (SD: .075) for young females and .715 (SD: .172) for elderly females. There is a significant difference between the two groups within the range of normal threshold.

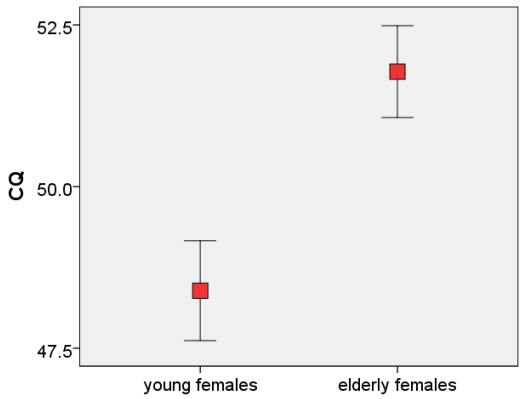

Figure 8. CQ between young and elderly females

In CQ, the mean value is 48.38% (SD: 3.71) for young females and 51.77% (SD: 2.10) for elderly females. There is a significant difference between the two groups.

4. Summary and Discussion

4.1 Summary

Major findings in this experiment can be summarized as follows.

(1) In pitch, the mean value for young males was lower than that for elderly males while the mean value for young females was higher than that for elderly females.

(2) In jitter, there was no significant difference between young male and female subjects as well as between elderly male and female subjects. However, there was a significant difference between young and elderly males as well as between young and elderly females.

(3) In CQ, there was a significant difference between young and elderly subjects. The mean value for young males was higher than that for elderly males while the mean value for young females was lower than that for elderly females.

4.2 Discussion

In this experiment, comparing with young males and females, the mean value of pitch for elderly females is lowered significantly while that for elderly males is raised significantly. This result is consistent with what Yamazawa & Hollien (1992) and Kim (2008) found in their studies.

It has been known that diminishing estrogen levels in elderly females may be a factor in lowering pitch, whereas diminishing testosterone levels in elderly males may contribute to a rising pitch (Hollien & Shipp, 1976).

In CQ, according to Choi (1994), there was no significant difference between young male (45%) and young female subjects (43%). On the other hand, according to Kim (2010) there was a significant gender difference; i.e. the mean value for young males was 49.28% while that for young females was 44.65%. (SD: 4.42) in sustained vowel /a/.

In the current study of CQ, there was no significant difference; the mean value was 50.36% (SD: 5.31) for young males and 48.38% (SD: 3.71) in sustained corner vowels.

According to Konstanopoulos et al. (2009), some voice variables can be considered as a sign of vocal instability. In this experiment, male subjects regardless of age difference generally show higher values of standard deviation of pitch and jitter than female subjects. In standard deviation of pitch, for instance, the mean values for young and elderly males were 18.73 and 20.56, respectively while those for young and elderly females were 12.82 and 13.08, respectively.

5. Concluding Remarks

It is known that EGG technique can be used with a variety of voice disordered patients as well as stutters, singers, deaf speakers, and normal speakers. The EGG is particularly useful when it is applied with other clinical measures and correlated with other observations such as High-speed films, videoendoscopy, and video stroboscopy of the larynx.

The Lx waveform, which depicts both sides of the vocal cord, can be used in speech clinics. For instance, the degree of

the sound's hyperfunction and hypofunction can be easily assesses by comparing information on the duration of the opening and closure of the vocal folds.

The present study emphasizes the use of objective instrumental techniques and more specifically electroglottography for the measurement of normal voices. It was shown that the mean pitch, range of pitch and jitter could reflect the vocal instability.

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