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A comparison of the phonation quotient between patients with voice disorders caused by benign vocal fold lesions and normal adults 20-80 years of age

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ABSTRACT

Background: A voice evaluation is an important first step in analyzing voice symptoms and determining appropriate treatment plans. The phonation quotient is a valid aerodynamic parameter in voice evaluations which is an indirect source of information for evaluating the valve function of the vocal folds of patients with voice disorders, especially patients with voice disorders caused by tumors of the vocal folds which is the most common cause in the patients with voice disorders.

Objective: The present study aims to determine and compare the phonation quotient between patients with voice disorders caused by benign vocal fold lesions and normal adults between 20-80 years of age.

Materials and methods: The participants comprised 40 adults with voice disorders caused by benign vocal fold lesions and 40 with normal voices. All participants' voices were evaluated in the Speech Clinic at Ramathibodi Hospital, Bangkok. The phonation quotient (PQ) was calculated by the ratio of vital capacity (VC) to the maximum phonation time (MPT). VC and MPT were measured using a phonatory aerodynamic system (PAS).

Results: The results of the present study indicated that the mean value of the PQ of adults with normal voices was 122.60 cc/sec (SD=16.36). The mean value of the PQ of adults with voice disorders caused by benign vocal fold lesions was 292.08 cc/sec (SD=97.14). The mean value of the PQ in the group with voice disorders caused by benign vocal fold lesions was significantly more significant than the mean value of the PQ in the group with normal voice.

Conclusion: The significant difference between the phonation quotient of adults with voice disorders caused by benign vocal fold lesions and adults with normal voice was that the PQ might be an indicator for indirect evaluation of the airflow leakage related to the efficiency of vocal fold movement during phonation. The PQ can be the optional voice measurement for monitoring and analyzing the outcomes of voice therapy.

Introduction

Voice disorders are impairments that affect a person's communications, social interactions, and occupations. They can also produce emotional and behavioral problems such as anxiety, emotional tension, and aggressive behavior, adversely affecting their quality of life.[1-3] The laryngeal pathology of the patients with voice disorders is diagnosed by an otolaryngologist, and their voice is evaluated by a speech-language pathologist (SLP).[4] Speech-language pathologists evaluate and diagnose voice problems, prepare treatment plans, and provide therapeutic services

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for patients with voice disorders. The factor that affected the successful results of speech therapy was the ability of SLPs to determine and evaluate the characteristics of their patients' voice problems.[4,5] The voice problems of patients with benign vocal fold lesions arise from incomplete glottic closure, which leads to airflow leakage during phonation, changing the voice by decreasing its loudness and pitch and increasing breathiness.[4,5] From the medical records of the Speech Clinic at Ramathibodi Hospital, Bangkok, the statistics about patients with communication disorders between 2016 and 2017 showed that there were 239 adult patients with voice disorders or 19.1 percent of all adult patients with communication disorders. Benign vocal fold lesions were the most common cause of voice disorders in this group of patients.[6]

Voice evaluations can be generally divided into two types: objective and subjective. A subjective evaluation is an auditory-perceptual evaluation upon which SLPs base their clinical decisions. If a clinician can only conduct a subjective evaluation, more than the voice information from the evaluation will be needed to decide on a proper treatment plan. As a result, an objective evaluation is needed to determine the most effective therapy for patients with voice disorders.[4,7,8] An objective evaluation, such as an acoustic and aerodynamic analysis, is instrumental. Normally, patients with voice disorders will have their maximum phonation time (MPT) evaluated between the steps of their voice therapy programs. These evaluations can be either subjective or objective. However, an additional parameter, called "phonation quotient", is an indirect clinical measurement. In addition to using clinical instruments, the phonation quotient (PQ) is defined as the ratio between two aerodynamic parameters: vital capacity (VC) and maximum phonation time (MPT).[8-12] Vital capacity is the maximum total volume of air that can be expelled after maximum inhalation.[4,9,13,14] Maximum phonation time is the maximum period a vowel sound can sustain after maximum inhalation.[8,9,15]

The VC and MPT of Thai people are different from those of European or American people because of the difference in lung capacity and body size.[15,16] These aerodynamic parameters can be non-invasive and easily measured using the Phonatory Aerodynamic System (PAS).[17] The PAS is an instrument generally used in voice clinics for measuring the airflow, pressure, and parameters associated with speech and voice production. The PAS has two handles attached to the instrument's body, including the required tubing, coupler, microphone, airflow head, face mask, and calibration syringe.

Furthermore, the phonation quotient is a proper aerodynamic parameter in voice evaluations because it indicates the amount of air expelled during phonation.[9,10] PQ is an indirect source of information for evaluating the valve function of the vocal folds of patients with voice disorders, especially patients with voice disorders caused by vocal folds' tumors that may lead to airflow leakage during phonation.[10,12,16] Therefore, one purpose of the present study is to determine the PQ of Thai adults by using the ratio between VC and MPT. Another purpose is to compare the PQ between Thai adults with voice disorders caused by benign vocal fold lesions and adults with normal voices of 20-80 years of age. The results of this study will inform speech-language pathologists about the differences in PQ between Thai adults with voice disorders caused by benign vocal fold lesions and Thai adults with normal voice, and they can use the PQ for an indirect evaluation of the efficiency of vocal fold movement during phonation, or the valve function of the vocal folds. This will enable them to monitor and analyze outcomes in each session after voice therapy and to reconsider the next steps of their voice therapy plans for patients with voice disorders.

Materials and methods

The present study's data was collected from December 2018 to July 2020. The details are as follows:

Participants

The number of participants was determined by sample size determination (two dependent means of phonation quotient for a pair-matched study), which was 80 participants. A total of 80 participants were divided into two groups. There were 40 new cases, 10 males and 30 females, in the group of adults with voice disorders caused by benign vocal folds lesions and 40 adults, 10 males, and 30 females, in the group of adults with a normal voice who were the relatives of patient or personnel at Ramathibodi Hospital. The age and gender of each participant in both groups were matched. The age difference between the participants in both groups was less than 5 years. Furthermore, the members of both groups agreed to participate in this study by signing an informed consent form. In addition to the COVID-19 pandemic, the participants were required to test the COVID-19 Antigen Testing Kit (ATK), and the test result was negative for COVID-19.

In the adults with voice disorders group, the participants were between 26 and 78 years, and the mean age was 49.30 years (SD=14.43). Furthermore, all participants in this group were diagnosed with voice disorders caused by benign vocal fold lesions by Otolaryngologists, and the types of benign vocal fold lesions were divided into 4 types: vocal nodules, vocal polyps, vocal cysts, and vocal masses. There were 22 participants: 8 males and 14 females with vocal nodules, 7 participants: 1 male and 6 females with vocal polyps, 9 females with vocal cysts, and 2 participants: 1 male and 1 female with vocal masses.

In the group of adults with normal voices, there were 37 participants who were the relatives of patients at the speech clinic and 3 participants who were personnel at Ramathibodi Hospital. The participants were between 20 and 80 years old, and the mean age was 48.90 (SD=14.48). All participants in the group of adults with normal voices were healthy adults who did not have diseases of the abdomen, respiratory system, or lung diseases. In addition, the results of their voice analyses were normal.

Participants who did not complete either the test of vital capacity (VC) or the test of maximum phonation time (MPT) by the Phonatory Aerodynamic System (PAS) were excluded.

Procedures

The procedures consisted of two steps: voice analyses to include participants and then aerodynamic analyses. The descriptions of the two steps are as follows:

1. Voice analyses for the inclusion of participants

The participants' voices were analyzed in subjective and objective assessments in a quiet room. Voice analyses were completed in approximately 15 minutes. The subjective assessments were based on the Thai Speech-Language and Hearing Association protocol for auditory perceptual voice analysis, which consisted of participant interviews and history records, respiratory analysis and behavioral voice misuse, auditory perceptual analysis of pitch and loudness, and auditory perceptual analysis of voice quality.[18] In the objective assessment or an instrumental evaluation by Vocal Assessment Program of the Dr. Speech software, version 5, designed by Daniel Z. Huang, Tiger DRS Inc, Shanghai, China, the voice of a participant was evaluated by sustaining the /a/ sound at comfortable pitch and loudness levels. The acoustic parameters of voice were analyzed that consisted including Jitter (%), Shimmer (%), standard deviation of the fundamental frequency or SDF0 (Hz), normalized noise energy or NNE (dB), and the estimated voice quality, which consisted of three parameters: hoarse voice, harsh voice, and breathy voice. Jitter, Shimmer, SDF0, and NNE defaults are 0.5%, 3%, 3 Hz, and -10 dB, respectively.

For voice analysis criteria of the group with normal voice, the results of the subjective and objective assessments: the acoustic parameters and the estimated voice quality of participants were in the normal range.

For the group with voice disorders, the results of participants' subjective and objective assessments were in the abnormal range.

2. Aerodynamic analyses

The vital capacity (VC) and maximum phonation time (MPT) of all participants were measured by using the Phonatory Aerodynamic System (PAS) model 6600 in a quiet room. Both aerodynamic analyses took approximately 15 min. Before aerodynamic analyses in each session, the face mask of the PAS was cleaned with an alcohol solution of 70%, and the airflow head of the PAS was calibrated. The result of the airflow head calibration, which is shown on the computer screen, must be the closest in capacity to 1 liter. After calibration, the VC and MPT of the participants were measured. The participant was informed about the method used to determine VC by breathing in through the nose as deeply as possible (maximum inhalation) and then expelling the air from the mouth as much as possible (maximum exhalation). Furthermore, the participant was informed about the method used to determine MPT by breathing in through the nose as deeply as possible (maximum inhalation) and sustaining the /a/ sound at comfortable pitch and loudness levels for as long as possible. During the tests, the face mask must completely cover the participant's mouth to prevent air leakage. After each session, the PAS face mask was cleaned with soapy water and Hibicet liquid (Savlon). Each of the determinations involved three trials.

Statistical analysis of the data

The statistical analysis of demographic data of all participants was reported by N (%), mean value, and SD.

Using the mean values of VC and MPT, each participant's average values of the VC and MPT were used to determine their phonation quotient (PQ). The PQ is the VC (cc.) ratio to MPT (sec).

After that, the mean value of the phonation quotient in adults with voice disorders and adults with normal voice was transformed by inverse square root (1/sqrt) for normal distribution. The differences in the transformation of the phonation quotient between adults with voice disorders and those with normal voices were analyzed by paired t-test.

Results

The results of the present study were divided into five parts, including the demographic data of the participants, the results of the voice analyses of the participants, the results of the acoustic parameters of the voice of the participants, the results of the aerodynamic analyses of the participants, and the results of the differences in the PQ between adults with voice disorders and adults with normal voice. The details of the results are shown in Table 1 to 5.

Table 1 Demographic data of the participants.

Characteristics	Normal voice (N=40)		Voice disorders caused by benign vocal fold lesions (N=40)			
	Relative of the patients	Personnel	Nodules	Polyps	Cysts	Masses
Gender, N (%)						
Male, 10 (25)	27 (90)	-	8 (80)	1 (10)	-	1 (10)
Female, 30 (75)	10 (100)	3 (10)	14 (35)	6 (15)	9 (22.5)	1 (2.5)
Age, Mean (SD)	48.90 (14.43)		49.30 (14.43)			

Table 2 The results of voice analyses of participants with voice disorders.

Voice analyses	Mild N (%)	Moderate N (%)	Severe N (%)	Total N (%)
Subjective assessment				
Voice disorders	8 (20)	19 (47.50)	13 (32.50)	40 (100)
Objective assessment*				
Hoarse voice	15 (42.86)	14 (40)	6 (17.14)	35 (100)
Harsh voice	5 (25)	6 (30)	9 (45)	20 (100)
Breathy voice	6 (15)	15 (37.5)	19 (47.5)	40 (100)

**Evaluation by Vocal Assessment Program of the Dr. Speech software, version 5, designed by Daniel Z. Huang, Tiger DRS Inc, Shanghai, China.*

Table 3 The results of acoustic parameters of the voice of the participants.

Acoustic parameters of voice*	Normal voice (N=40) Median (QD)	Voice disorders caused by benign vocal fold lesions (N=40) Median (QD)
Jitter	0.19 (0.05)	0.38 (0.48)
Shimmer	1.23 (1.06)	2.35 (2.80)
SDF0	1.36 (0.74)	2.36 (1.65)
NNE	-15.17 (3.50)	-8.17 (4.89)

**Evaluation by Vocal Assessment Program of the Dr. Speech software, version 5, designed by Daniel Z. Huang, Tiger DRS Inc, Shanghai, China.*

Table 4 The results of aerodynamic analyses of the participants.

Groups		Aerodynamic analyses		
		VC (cc)	MPT (sec)	PQ (cc/ sec)
		Mean (SD)	Mean (SD)	Mean (SD)
Normal voice (N=40)	Female (30)	2050.67 (266.38)	17.26 (3.69)	121.66 (17.52)
	Male (10)	2454.00 (374.20)	19.71 (3.39)	125.44 (12.58)
	Total (40)	2151.50 (341.12)	17.87 (3.73)	122.60* (16.36)
	95% confidence interval			117.37-127.83
Voice disorders (N=40)	Female (30)	2240.00 (308.98)	8.31 (2.91)	299.64 (103.68)
	Male (10)	2849.00 (465.58)	11.14 (3.10)	269.40 (74.07)
	Total (40)	2392.25 (438.56)	9.02 (3.17)	292.08* (97.14)
	95% confidence interval			261.01-323.14

**The mean difference of PQ between the two groups was 169.48 cc/sec.*

Table 5 The results of differences in phonation quotient between adults with voice disorders and those with normal voice.

Groups	PQ (1/sqrt)		95 % Confidence interval		*t*	sig
	Mean	SD				
Normal voice (N=40)	0.061	0.010	0.058	0.064	-16.632	<0.001
Voice disorders (N=40)	0.091	0.006	0.089	0.093		

The results of the voice analyses of the participants indicated that the results of subjective and objective assessment in participants with normal voices were in the normal range. On the other hand, subjective and objective assessment results in participants with voice disorders were in the abnormal range. The details of the voice analyses of the participants with voice disorders are shown in Table 2. In addition, the details of the acoustic parameters of the participants' voices are shown in Table 3.

From Tables 4 and 5, the summary of the results indicates that the mean value of the PQ of adults with normal voice was 122.60 cc/sec (SD=16.36), corresponding to a 95% confidence interval of 117.37-127.83 cc/sec and the mean value of the PQ of adults with voice disorder caused by benign vocal fold lesions was 292.08 cc/sec (SD=97.14), corresponding to a 95% confidence interval of 261.01-323.14 cc/sec. In addition, the transformation of the PQ of adults with voice disorders was less than that of adults with normal voice, and the differences were statistically significant (p<0.001). In other words, the PQ of adults with voice disorders (292.08 [97.14] cc/sec) was higher than adults with normal voice (122.60 [16.36] cc/sec),

and the mean difference between the two groups was 169.48 cc/sec. The differences in the PQ between the two groups were statistically significant (p<0.001).

Discussion

From the results of the PQ of adults with normal voices, the mean values of the PQ were 121.66 cc/sec (SD=17.52) for females and 125.44 cc/sec (SD=12.58) for males. The mean values of the PQ for females and males of the present study were in the standard range of adults with normal voice of the study of Hirano, Koike, and Von Leden[10] which agreed with the study of Dobinson and Kendrick,[19] and Morsomme *et al*.[20] The standard range of the PQ for people with normal voice was between 78.00 cc./sec and 241.00 cc/sec (mean=137 cc/sec) for females, and between 69.00 cc/sec and 307.00 cc/sec (mean=145 cc/sec) for males.[10] The PQ of the present study was defined as the ratio between two aerodynamic parameters: the VC and the MPT. In this study, the mean values of the VC were 2050.67 cc. (SD=266.38) for females and 2454.00 cc. (SD=374.20) for males. The mean values of the MPT were 17.26 sec (SD=3.69) for females and 19.71 sec (SD=3.39) for males. The mean values of VC and MPT were in the range of the VC and the MPT in Thai people of Limprasert's study.[15]

Furthermore, the mean value of the PQ of adults with voice disorders caused by benign vocal fold lesions was 292.08 cc/sec, greater than 122.60 cc/sec of adults with normal voice. The lowest value of the PQ in the group of participants with voice disorders was greater than the highest value of the PQ in the group of participants with normal voices. The differences in the mean value of the PQ between both groups of the present study were statistically significant (p<0.01). This finding of the present study agrees with the studies of Hirano, Koike, and Von Leden[10], Iwata and Von Leden,[11] and Aghajanzadeh *et al*.[21] The high PQ values might be interpreted as the tumors of the vocal folds causing incomplete glottic closure[22] and interfering with vocal fold vibrations. Poor vocal fold approximation then causes airflow leakage during phonation, increasing breathiness, and shortening of MPT.[4,5,10,23-25] Breathy voice was one out of three characteristics of objective assessment of the present study, which was found in all of the participants with voice disorders. Moreover, the NNE is the acoustic parameter that is related to a breathy voice. In this study, the NNE value in the group of participants with voice disorders was greater than -10 dB, resulting from an incomplete closure of the glottis. In addition, the short MPT is related to the high PQ value because the MPT has a negative correlation with the PQ. In other words, when MPT decreases, PQ values increase.[10]

Conclusion

The significant difference between the phonation quotient of adults with voice disorders caused by benign vocal fold lesions and adults with normal voice was reflected that the PQ might be an indicator for indirect evaluation of the airflow leakage related to the efficiency of vocal fold movement during phonation. Moreover, the PQ can monitor and analyze therapy outcomes for patients with voice disorders. So, the PQ is one of the airflow measurements in aerodynamic analysis, the optional measurement for voice assessments. Speech and language pathologists (SLPs) can choose the PQ for evaluation in patients with voice disorders caused by laryngeal diseases that affect incomplete glottic closure.

Limitations

The present study was a paired-match study that aimed to determine and compare the phonation quotient between Thai adults with voice disorders caused by benign vocal fold lesions and adults with normal voices. Each participant between both groups was matched by age and gender. Furthermore, the number of participants was not balanced for gender. In addition, there were various types, sites, and sizes of benign vocal fold lesions in the voice disorders group.

Recommendations

For further studies, the participants should be divided equally into genders to better determine and compare the phonation quotient between females and males. The factors that affected the change in the phonation quotient, including the differences in the types, sites, and sizes of benign vocal fold lesions, should be considered. In addition, the instrument Phonatory Aerodynamic System: PAS, can be used for aerodynamic analysis in other types of voice disorders, including organic-physiological voice disorders and functional voice disorders.

Conflict of interest

The authors declare that there is no conflict of interest.

Ethics approval

The present study received approval from the Ethical Committee of the Ramathibodi Hospital, COA. No. MURA2018/863

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