

Phonation Threshold Flow and Phonation Threshold Pressure in Patients with Adductor Spasmodic Dysphonia

Choi, Seong Hee¹⁾, Jiang, Jack J., Yun, Bo Ram, Lee, JiYeoun, Lim, Sung-Eun, Choi, Hong-Shik²⁾

ABSTRACT

This study investigated the characteristics of two aerodynamic indices, PTP (Phonation threshold pressure) and PTF (Phonation threshold flow) in patients with ADSD (adductor spasmodic dysphonia) and to see if two new aerodynamic indices can differentiate between normal and ADSD group. Additionally, PTP and PTF values were compared in terms of overall severity of ADSD in the patient group. The severity of ADSD was rated on a 7-point rating scale by two experienced speech language pathologists. The Kay Elemetrics Phonatory Aerodynamic System (PAS) (Kay Elemetrics Corp., Lincoln Park, NJ) was used to collect PTP and PTF measurements from 16 female normal subjects, 31 female patients with ADSD.

Significantly lower PTF values ($P < 0.05$) were observed in ADSD when compared to those of normal control. Also, significantly lower PTF values in severe ADSD patients ($P < .001$). However, PTP could not distinguish patients with ADSD from control groups ($P = 0.119$) and among the ADSD groups according to the severity ($P = 0.177$).

Consequently, PTF was more sensitive than PTP which might differentiate between normal speakers and ADSD and among different levels of severity within ADSD, suggesting that PTF could be a useful diagnostic parameter to measure the aerodynamic function of ADSD and provide the neurolaryngeal dysfunction in patients with ADSD.

Keywords: aerodynamic measures, PTF, PTP, perceptual severity, Adductor Spasmodic Dysphonia

1. Introduction

Spasmodic dysphonia is a focal dystonia in the larynx and has been considered as one of the neurolaryngopathology which derives from dysfunction of the central nervous system [1-3]. Adductor spasmodic dysphonia (ADSD) is the more common type of spasmodic dysphonia. In adductor spasmodic dysphonia, hyperadduction of the vocal folds interferes with free-flowing

speech and involuntary hyperadduction of vocal fold blocks the air flow and causes to produce a strained strangled laryngeal voice and voice arrests or phonatory breaks [4-5]. Patients with ADSD frequently perceived laryngeal tightness and vocal effort with laryngeal spasms [5].

De Biase [6] mentioned that the stronger the adductor forces which indicates the cases of severe dysphonia, the higher the subglottic pressure required to initiate vocal fold vibration and the initiation of phonation [6]. Botulinum toxin type A (BOTOX[®]) injection into the laryngeal muscles has been considered as optimal option of the current clinical practice for patients with ADSD [7-9].

A number of studies have explored aerodynamic measures in adductor spasmodic dysphonia. In aerodynamic studies for ADSD, maximum phonation time [10-11], subglottal air pressure [12], laryngeal resistance [12], airflow [12-13] have been measured. Airflow in patients with ADSD showed lower than normal airflow rates [13-16] and significantly higher air pressure, larger coefficient of variation (CV) of airflow and higher laryngeal

1) Department of Surgery, Division of Otolaryngology-Head and Neck Surgery, University of Wisconsin Medical School, 5745a Medical Sciences Center, laryngeal physiology lab, 1300 University Avenue, Madison, WI, 53706, USA E-mail: choi @ surgery.wisc.edu

2) Department of Otorhinolaryngology, Yonsei University College of Medicine, Institute of Logopedics and Phoniatics Corresponding author.

E-mail: hschoi @yuhs.ac

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resistance during phonation [10] and lower MPT were observed in patients with ASD [11].

Recently, phonation threshold flow (PTF) is a new parameter of aerodynamic, along with phonation threshold pressure(PTP) has been used to measure the aerodynamic functions of pathologic voices [17] and excised larynx set-up [18-19]. PTF was positively correlated with vocal fold elongation [18] and negatively correlated with hydration [19]. In clinical use, the higher PTF values noted in patients with vocal nodules and vocal polyps due to an incomplete glottal closure and increased vocal fold mass and thickness and PTF could differentiate between normal and pathological voices in benign lesions of vocal folds [17]. Phonation threshold pressure (PTP), the minimum subglottal pressure required to initiate vocal fold oscillation [20-21] and phonation threshold flow (PTF), defined as the minimum glottal airflow required to initiate vocal fold vibration are noninvasive measures and have been considered as indicatives of the biomechanical properties of the vocal folds which can provide valuable laryngeal functions [18-19]. PTF also provides a measure of the ease of phonation with PTP [22].

The aim of study was assessment of two new aerodynamic measures, PTP and PTF of ASD in conjunction with characteristics of perceptual severity.

2. Materials and methods

2.1 Participants

31 patients who were diagnosed with ASD by laryngologists and 16 normal speakers with no history of vocal pathologies were participated in this study. All patients were females and the mean age of the women patients was 48 years ranging from 32 to 69 years. The time of spasmodic dysphonia onset ranged from 1 to 8 years. ASD patients were recruited from the Kangnam Severance Hospital, Voice Clinic of Yonsei University College of Medicine. All normal speakers identified to have healthy vocal folds with stroboscopic examination.

2.2 Data collection

The protocol was approved by institutional review board (IRB) in Yonsei University and the University of Wisconsin-Madison for research on human subjects. All participants signed up the consent forms to participate in this study. A voice digital set of recorded voice samples from 31 patients with ASD was used to rate overall severity of ASD symptoms. All patients were diagnosed with ASD made by laryngologists and all patients had history to inject BOTOX®. Voice recording were made with

Computerized Speech Lab (CSL), Model 5105, (Kay Elemetics, USA) and all patients were asked to phonate sustained /a/vowels for 3 seconds three times, and to read a paragraph “kaeul”.

PTF and PTP measurements were collected using the Phonatory Aerodynamic System (PAS), Model 6800 (Kay Elemetics, USA).

For measuring the PTF, participants were instructed to initiate phonation at a soft intensity and decrease intensity for 3 to 5 seconds until no phonation was detected. All subjects repeated the PTF trials 10 times, resting for 5 seconds between trials given in <Figure 1>.

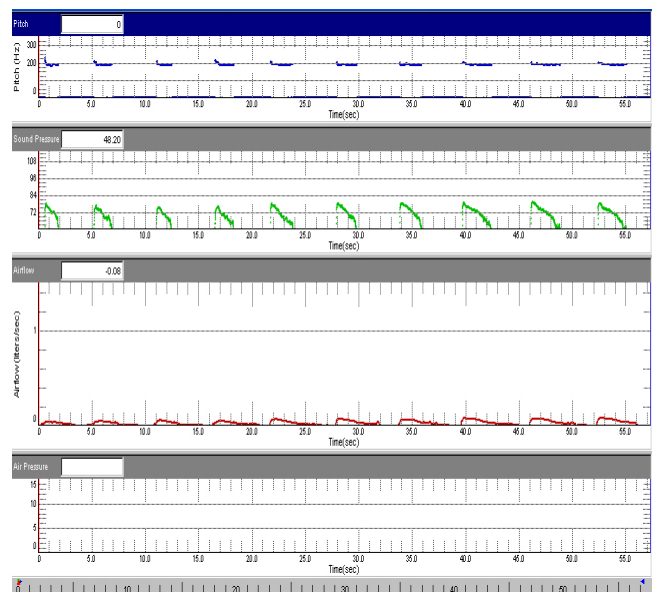


Figure 1. 10 trials for PTF measures from a patient with ASD in PAS program

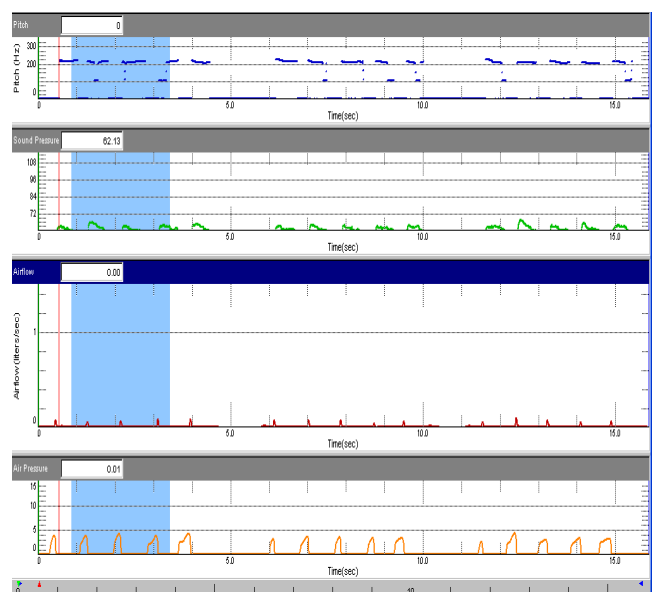


Figure 2. PTP trials three times from a patient with ASD in PAS program

For measuring the PTP, Each subject was asked to produce /pa, pa, pa, pa, pa/ as softest as possible and repeated the PTP trials 3 times <Figure 2>.

2.3 Data analysis

For perceptual analysis of overall severity, Unified Spasmodic Dysphonia Rating Scale (USDRS) described by Stewart et al. (1997) was used [23]; Two speech language pathologists who are experienced with ADSD patients (5 years: 3 ~ 7) rated the overall severity using 7-point equal-appearing interval (EAI) scale (1= no symptom, 2 = mild, 3 = mild to moderate, 4 = moderate 5 = moderate to severe, 6 = severe, 7 = profound) and two ratings were averaged. Then, ADSD patients were classified into three groups according to the severity; mild (2-3), moderate (4-5), severe (6-7).

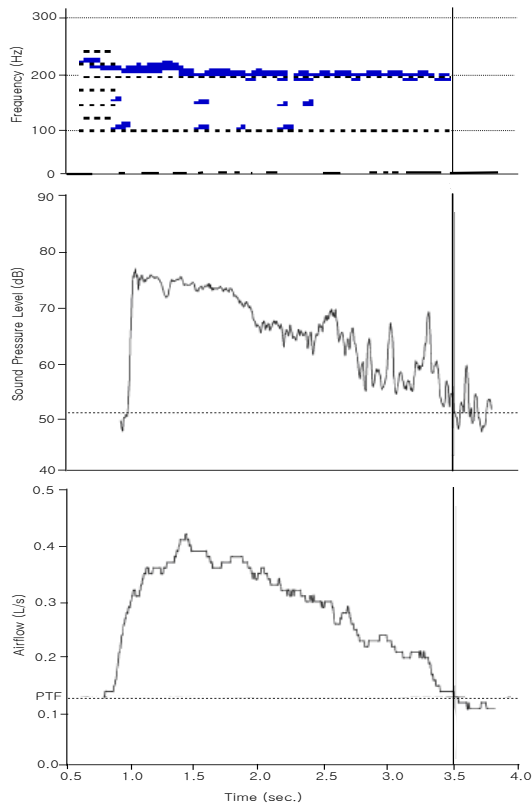


Figure 3. An example of estimation of phonation threshold flow (PTF). Top represents fundamental frequency(Hz), with middle and bottom indicating the sound pressure level (dB) and airflow (L/s) from a female with ADSD.

PTF values were estimated the airflow at the point where phonation ceased which defined as the point where SPL decreased to approximately 50dB as shown in <Figure 3> and then finally 10 trials of PTP values averaged for each participant.

PTP values were estimated from middle three /pa/ syllables for each trial and averaged 3 trials for each participant <Figure 2>.

2.4 Statistical analysis

Mann-Whitney Rank Sum Test was conducted to compare between control and patients with ADSD for two aerodynamic parameters and Kruskal -Wallis One way Analysis of Variance on Ranks was performed to compare the PTF values among the patient groups with ADSD in terms of severity. Correlation coefficient was obtained to measure the inter-rater reliability. All significant levels were 95%.

3. Results

3.1 Rating of severity of ADSD symptom

The mean of overall severity of patients with ADSD was 4.39 \pm 1.71, which indicates moderate degree of symptom. 31 Patients with ADSD groups were classified into three subgroups in terms of severity; 11 mild (2-3), 7 moderate (4-5), 13 severe (6-7).

Inter-rater agreement of overall severity calculated by means of coefficient was 0.83.

3.2 Phonation threshold flow (PTF)

The summaries of 10 trials of PTF for normal and ADSD patients are given in <Table 1> and <Table 2>. The means of PTF values were 0.06 \pm 0.06 L/sec, 0.03 \pm 0.02 L/sec, respectively, for normal speakers and patients with ADSD. <Figure 4> shows that there were significant lower PTF values in patients with ADSD ($p < .05$).

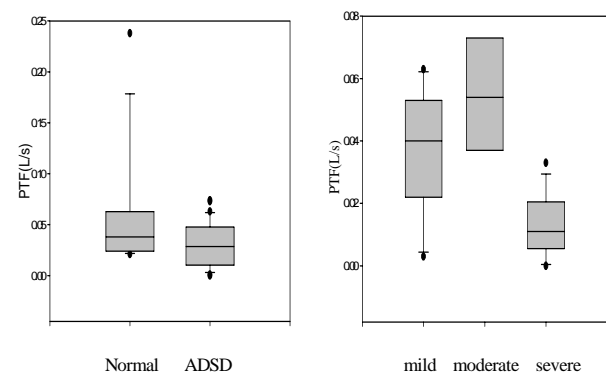


Figure 4. Box plots for Phonation Threshold Flow (PTF) for normal and ADSD groups and three different severity levels of ADSD groups. The midline represents the median, with the lower and upper boundaries of the box indicating the first and third quartile, respectively.

In terms of severity of symptom of ADSD, mean and standard deviation of PTF values in mild, moderate, and severe group were 0.04 \pm 0.02, 0.05 \pm 0.02, 0.01 \pm 0.01, respectively and as shown

in <Figure 4>, significantly lower PTF values were found in severe ASD (p<.001).

3.3 Phonation threshold Pressure (PTP)

The mean and standard deviation of 3 trials of PTP were summarized in <Table 3>. The mean and standard deviation of PTP for normal speakers was 3.59 ± 1.35 whereas 2.98 ± 1.48 for patients with ASD. No significant differences were observed between two groups (p=0.092).

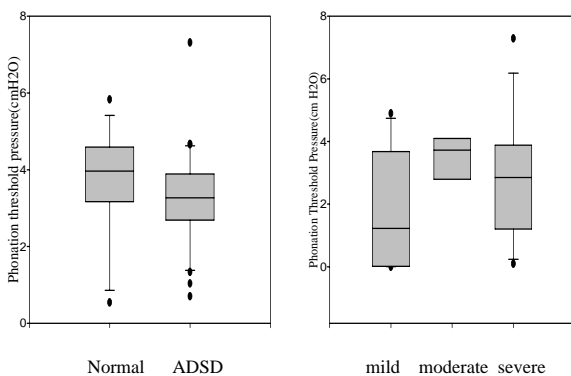


Figure 5. Box plots of phonation threshold pressure (PTP) for normal and ASD groups and for ASD subgroups at the different severity levels .

Based on the severity of symptoms of ASD, mean and standard deviation of PTP values in mild, moderate, and severe group were 1.84 ± 1.99 , 3.40 ± 0.80 , 2.79 ± 1.94 , respectively. No significant differences were found among the groups (p=0.177).

4. Discussion and Conclusion

To better understanding of pathophysiology of ASD, aerodynamic evaluation has been performed in ASD. In the previous studies, variation of phonatory airflow was quantified using the coefficient of variation (CV), which was calculated by dividing the standard deviation of airflow by average airflow. Adams et al. (1996) found that the average CV of airflow values obtained from the SD were significantly higher than those of the normal subjects and the CV of airflow most clearly distinguished the SD from the normal subjects for quantifying the irregular aspects of airflow production in SD [10]. This aerodynamic index was considered a good indicative of presence or absence of tremor in ASD. Furthermore, mean airflow rates for ASD have been evaluated. However, the results in literature have been controversial. The airflow rates in ASD were lower than the

normal range with a markedly high variability [13-14] whereas the airflow rates were within the normal range. Thus, mean airflow rate does not seem to be a sensitive aerodynamic index for discriminating the ASD voice from normal speakers.

In the present study, new aerodynamic indices, phonation threshold flow and phonation threshold pressure were measured to investigate the potential diagnostic parameters for ASD. Differences in PTF between normal and patients with ASD were found and our results showed that PTF in ASD was significantly lower than the normal range. It is possible that ASD group in this study showed relatively moderate severity of symptoms in the perceptual ratings. Moreover, we investigate PTF in more detail in terms of overall severity of ASD symptoms using the 7 - point rating scale of Unified Spasmodic Dysphonia Rating Scale (USDRS) developed by Stewart et al. [23] which is a systematic standardized evaluation of severity of ASD. According to the previous study for reliability of ASD severity [26], inter and intra-reliability of experts in assessing the severity of ASD were excellent showing 93% and 96%, respectively although higher agreement towards extremes of the rating scale and lower agreement in the middle of the rating scale. In this study, we measured only inter-rater reliability and relatively a good agreement on overall severity was achieved. Even though there was no difference between mild and moderate group of ASD, PTF was significantly decreased in severe ASD group. Perceptually, ASD group with severe symptoms was characterized by more strained and strangled voice and phonatory effort and laryngeal spasms which lead to produce a lower airflow when the phonation ceased. Regner et al.(2008) noted that onset PTF, the airflow required to initiate phonation, is higher than offset PTF, the airflow at the point phonation ceases and thus, PTF measurements at the offset of phonation provides a more accurate measure of airflow threshold [24]. Therefore, we also applied the same method to measure the PTF at the point where phonation ceased which defined as the point where SPL decreased to approximately 50dB as previous studies [17], [24]. In ASD, a low PTF airflow was expected in the condition related to excessive vocal closure.

In contrast, PTP was not significantly different between normal and ASD group although Witsell (1994) found higher subglottal air pressure was obtained in ASD [19]. Similarly, there were no significant differences among the ASD groups in terms of severity. It is possible that the softest voice for measuring the PTF might be easy to phonate which could help to reduce the ASD symptoms and thereby the PTP was not influenced by soft

voice production condition. In a previous study, Verdolini-Marston et al., (1990), to estimate PTP noninvasively, they measured the minimum subglottal pressure during soft phonation as the point at which vocal fold oscillation can begin [25]. In this study, the participants were instructed to speak as softly as possible, but not whisper as described in the Verdolini-Marston's study. At the PTP task, the patients with ADSD yielded the variable PTP values than those of normal speakers, which were not consistent during 5 times /pa/ production. Due to this variability, we tried to estimate the middle three /p/ productions from each trail and five /p/ productions for analysis. Since we anticipated it might be hard to product for patients with ADSD first /pa/ and last /pa/ due to phonatory characteristic of ADSD, we compared with 5 /p/ productions and the middle three /p/ productions. Nevertheless, we did not find any significant differences between two estimations.

As a consequence, PTF parameter was a more sensitive indicator to identify ADSD symptoms and severity than PTP in our study. Jiang and Tao also predicted that PTF could be more sensitive to subtle changes in laryngeal tissue properties, glottal configuration, and vocal tract loading [22]. Our results showed that PTF can be a useful aerodynamic indicator of forceful phonation and could be used for a potential diagnostic parameter for clinical application in patients with spasmodic dysphonia and it can allow the discrimination of ADSD from normal speakers. In the future research, PTF also can be used to investigate differential diagnosis between adductor and abductor spasmodic dysphonia and treatment outcomes and efficacy of BOTOX[®] injection in spasmodic dysphonia.

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• **Choi, Seong Hee**

Address: Department of Surgery, Division of Otolaryngology - Head and Neck Surgery, University of Wisconsin Medical School, 5745A Medical Sciences Center, 1300 University Avenue, Madison, WI, 53706

Affiliation : UW Laryngeal Physiology Lab.

Telephone: +1- 714-309-6012

Email: choi@surgery.wisc.edu

Research interests: voice disorder, dysphagia, tissue engineering etc.

2007 ~ present Postdoctoral Fellow.

Ph.D., Dept. of Speech and Language Pathology, Yonsei Univ., 2006

• **Jiang, Jack J.**

Address : Department of Surgery, Division of Otolaryngology - Head and Neck Surgery, University of Wisconsin Medical School, 5745a Medical Sciences Center, 1300 University Avenue, Madison, WI 53706.

Affiliation : UW Laryngeal Physiology Lab.

Telephone : +1- 608-265-7888

E-mail : jjjiang@wisc.edu

Research Interests: the vibratory properties of the vocal folds via studies of excised larynges, biomechanical modeling, aerodynamics, and analysis of laryngeal microstructure, speech signal processing, etc.

1998 ~ present Professor, Division of Otolaryngology—Head and Neck Surgery

Ph.D., Speech Pathology and Audiology, Univ. of Iowa, 1991. M.D., Shanghai Medical Univ., 1983.

• **Yun, Bo Ram**

Address : Kangnam Severance Hospital, Yonsei University College of Medicine. Institute of Logopedics and Phoniatics, 612 Enjuro Kangnamgu, Seoul, Korea.

Affiliation : Department of Otorhinolaryngology, Institute of Logopedics and Phoniatics.

Telephone : +82-2-2019-3460

E-mail : eas7884@lycos.co.kr

M.S, Dept. of Speech and Language Pathology, Yonsei Univ., 2010

Research Interests : voice disorder

• **Lee, JiYeoun**

Address: Department of Surgery, Division of Otolaryngology -Head and Neck Surgery, University of Wisconsin Medical School, 5745A Medical Sciences Center, 1300 University Avenue, Madison, WI, 53706

Affiliation : UW Laryngeal Physiology Lab.

Telephone: +1-213-598-4410

Email: leeji@surgery.wisc.edu

Research interests: speech signal processing - voice measurement in patients with laryngeal pathology, etc.

2008 ~ present Postdoctoral Fellow.

Ph.D., Dept. of Information & Communications Engineering, KIST, 2008.

• **Lim, Sung-Eum**

Address : Kangnam Severance Hospital, Yonsei University
College of Medicine. Institute of Logopedics and
Phoniatics, 612 Enjuro Kangnamgu, Seoul, Korea.
Affiliation : Department of Otorhinolaryngology, Institute of
Logopedics and Phoniatics.
Telephone : +82-2-2019-3460
E-mail : selim0424@hanmail.net
M.S, Dept. of Speech and Language Pathology, Yonsei Univ.,
2005.
Research Interests : resonance disorder, voice disorder

• **Choi, Hong-Shik**, Corresponding author

Address : Kangnam Severance Hospital, Yonsei University
College of Medicine. Institute of Logopedics and
Phoniatics, 612 Enjuro Kangnamgu, Seoul, Korea.
Affiliation : Department of Otorhinolaryngology, Institute of
Logopedics and Phoniatics.
Telephone : +82-2-2019-3460
E-mail : hschoi@yumc.yonsei.ac.kr
Research Interests: laryngeal physiology, laryngeal
Transplantation, Development of Electrolarynx and new
phonosurgery methods
1989 ~ present Professor, Department of Otorhinolaryngology
Ph.D., Yonsei University College of Medicine, 1986
M.D., Yonsei University College of Medicine, 1978

Table 1. PTF values in normal group

	PTF 1	PTF 2	PTF 3	PTF 4	PTF 5	PTF 6	PTF 7	PTF 8	PTF 9	PTF 10	Average
N1	0.09	0.06	0.06	0.06	0.06	0.06	0.06	0.04	0.07	0.07	0.06
N2	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.03	0.04	0.02
N3	0.02	0.03	0.04	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02
N4	0.05	0.04	0.04	0.03	0.02	0.04	0.03	0.04	0.03	0.04	0.04
N5	0.05	0.03	0.03	0.03	0.02	0.04	0.02	0.05	0.03	0.04	0.03
N6	0.07	0.07	0.08	0.1	0.04	0.07	0.04	0.06	0.05	0.04	0.06
N7	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.06	0.07	0.04
N8	0.03	0.03	0.03	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.02
N9	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03
N10	0.02	0.02	0.02	0.07	0.04	0.04	0.02	0.03	0.03	0.05	0.03
N11	0.18	0.15	0.14	0.16	0.14	0.15	0.16	0.16	0.16	0.13	0.15
N12	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02
N13	0.04	0.04	0.05	0.05	0.04	0.04	0.03	0.04	0.03	0.04	0.04
N14	0.13	0.14	0.12	0.13	0.14	0.12	0.12	0.11	0.12	0.15	0.13
N15	0.26	0.24	0.21	0.21	0.21	0.17	0.26	0.27	0.29	0.26	0.24
N16	0.08	0.06	0.05	0.03	0.04	0.04	0.05	0.05	0.04	0.06	0.05
Mean	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.06
SD	0.07	0.06	0.05	0.06	0.06	0.05	0.07	0.07	0.07	0.07	0.06

N; Normal

PTF; Phonation Threshold Flow

Table 2. PTF values in patients with ADSD.

	PTF 1	PTF 2	PTF 3	PTF 4	PTF 5	PTF 6	PTF 7	PTF 8	PTF 9	PTF 10	Average
P1	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.008
P2	0.07	0.02	0.04	0.04	0.04	0.05	0.04	0.07	0.07	0.09	0.053
P3	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.012
P4	0.01	0.02	0.02	0.01	0.03	0.03	0.02	0.03	0.03	0.02	0.022
P5	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.011
P6	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
P7	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03
P8	0.05	0.06	0.13	0.09	0.07	0.07	0.06	0.1	0.04	0.07	0.074
P9	0.02	0.03	0.03	0.03	0.06	0.04	0.03	0.04	0.03	0.04	0.035
P10	0.06	0.05	0.06	0.07	0.07	0.06	0.04	0.06	0.05	0.07	0.059
P11	0.05	0.06	0.06	0.06	0.05	0.06	0.09	0.08	0.04	0.04	0.059
P12	0.04	0.02	0.05	0.04	0.01	0.09	0.08	0.05	0.05	0.04	0.047
P13	0.06	0.04	0.09	0.04	0.03	0.11	0.1	0.11	0.04	0.11	0.073
P14	0.06	0.06	0.06	0.06	0.08	0.04	0.03	0.05	0.04	0.06	0.054
P15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P16	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.03	0.05	0.019
P17	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.05	0.01	0.037
P18	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.009
P19	0.04	0.02	0.02	0.01	0.01	0.03	0.02	0.03	0.02	0.02	0.022
P20	0.04	0.02	0.02	0.03	0.04	0.04	0.03	0.04	0.04	0.05	0.035
P21	0.03	0.01	0.01	0.02	0.03	0.03	0.01	0.06	0.01	0.03	0.024
P22	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.003
P23	0.06	0.07	0.05	0.07	0.07	0.03	0.04	0.03	0.03	0.03	0.048
P24	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.013
P25	0.04	0.03	0.04	0.04	0.02	0.04	0.03	0.03	0.07	0.06	0.040
P26	0.05	0.03	0.02	0.03	0.03	0.04	0.02	0.03	0.04	0.04	0.033
P27	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.010
P28	0.05	0.04	0.05	0.06	0.07	0.09	0.07	0.06	0.07	0.07	0.063
P29	0.03	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.015
P30	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.06	0.05	0.042
P31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.001
Mean	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.030
SD	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.020

P; Patient with adductor spasmodic dysphonia

PTF; Phonation Threshold Flow

Table 3. PTP values in normal and ADSD.

	PTP 1	PTP 2	PTP 3	Average		PTP 1	PTP 2	PTP 3	Average		PTP 1	PTP 2	PTP 3	Average
N1	4.3	3.19	2.92	3.47	P1	1.66	2.95	3.95	2.85	P17	2.16	2.42	1.2	1.93
N2	2.47	2.74	2.96	2.72	P2	4.59	3.97	4.59	4.38	P18	0.81	0.88	0.65	0.78
N3	6.22	6.06	5.23	5.84	P3	3.56	5.21	4.15	4.31	P19	3.16	3.35	3.60	3.37
N4	3.71	3.19	2.88	3.26	P4	7.08	6.45	8.33	7.29	P20	2.06	2.09	3.18	2.44
N5	3.51	3.57	2.91	3.33	P5	2.48	1.58	0.85	1.64	P21	4.61	4.24	4.71	4.52
N6	4.32	4.01	3.45	3.93	P6	3.72	3.77	3.99	3.83	P22	0.23	0.80	0.35	0.46
N7	4.90	3.65	4.60	4.38	P7	0.08	0.07	0.07	0.07	P23	3.76	4.60	3.20	3.85
N8	4.18	3.65	3.64	3.82	P8	3.60	2.92	3.75	3.42	P24	3.25	3.41	3.7	3.46
N9	4.75	4.58	4.40	4.58	P9	4.20	3.48	2.06	3.25	P25	3.41	3.17	2.46	3.01
N10	0.67	1.00	1.27	0.98	P10	4.48	4.68	5.53	4.90	P26	3.39	2.57	2.09	2.68
N11	4.17	5.25	4.98	4.80	P11	4.60	3.74	3.95	4.10	P27	3.02	2.86	3.70	3.19
N12	4.64	5.28	4.82	4.91	P12	2.52	2.46	2.16	2.38	P28	3.67	2.88	2.72	3.09
N13	3.89	4.18	3.62	3.90	P13	2.77	2.81	2.81	2.80	P29	3.48	4.19	3.50	3.72
N14	0.49	0.65	0.59	0.58	P14	3.09	3.76	3.10	3.32	P30	2.58	1.83	3.03	2.48
N15	3.28	4.63	3.71	3.87	P15	0.20	0.03	0.07	0.10	P31	3.57	3.74	2.22	3.18
N16	2.99	3.29	2.97	3.08	P16	2.04	1.25	2.25	1.85					
Mean				3.59										2.98
SD				1.35										1.48

N; Normal, P; Patient with adductor spasmodic dysphonia

PTP; Phonation Threshold Pressure