A Comparison of the s/z Ratio to Instrumental Aerodynamic Measures of Phonation

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Summary: Objective. The purpose of this study was to examine how the s/z ratio and instrumental measures of laryngeal valving and voicing efficiency.

Study Design. Prospective, cohort design.

Methods. Fifteen adult males (mean age 28.3 years) and 15 adult females (mean age 29.2 years) with normal voice quality were recruited and compared on productions of the s/z ratio and instrumental aerodynamic measures. The aerodynamic measures included vital capacity, maximum phonation time, airflow rate during sustained and sentence production, subglottal pressure, and laryngeal airway resistance. These measures were obtained on the Phonatory Aerodynamic System Model 6600. Statistical analyses included a univariate analysis of variance to examine for differences between sexes for all the variables, and between the s/z ratios for each of the three trials. Pearson's Product Moment Correlations were performed to identify the strength and nature of any significant relationships between the s/z ratio and instrumental aerodynamics.

Results. There were significant differences in the mean values between males and females only for the measures of vital capacity and maximum phonation time. There were no significant differences between the three trials for the s/z ratio. There was a significant moderate negative correlation between the s/z ratio and laryngeal airway resistance in females and between the s/z ratio and sentence airflow rate in males.

Conclusions. The s/z ratio demonstrated only a moderate correlation with limited instrumental measures of laryngeal valving. In the absence of clear evidence of its ability to accurately assess laryngeal valving, the s/z ratio should be used in combination with other instrumental measures of laryngeal aerodynamics for a better representation of aerodynamic functioning.

Key Words: s/z ratio−Aerodynamics−Voice assessment−Laryngeal valving−Laryngeal airway resistance −Sentence airflow rate.

INTRODUCTION

The ability of the vocal folds to control the air through the upper airway and serve as a laryngeal valve is central to the process of phonation. Adequate glottic closure provides the necessary resistance required to build subglottal pressure, but not so much resistance that excessive air and effort is required to overcome it for the vocal fold vibratory cycle. Laryngeal valving is instrumental in the resultant voice quality and loudness.

The s/z ratio, as a measure of laryngeal valving, was first suggested by Boone[1] to combine information from maximum phonation tasks with and without voicing. The s/z ratio task is performed by sustaining /s/ maximally followed by sustaining /z/ maximally. A ratio of the duration for /s/ to the duration for /z/ gives the resultant value. It was hypothesized that in a healthy vocal system, the addition of voicing to the /s/, in order to produce the /z/, should not affect the duration of sustained expiration as the vocal folds should be able to valve the airflow appropriately. In previous normative studies, an s/z ratio close to 1.0 was considered acceptable.[2−4] In a disordered system, the glottal valving function is disrupted, either due to a larger than normal glottal gap, or due to vocal hyperfunction and increased muscle tension. In individuals with vocal fold pathology, s/z ratios are expected to be greater than 1.2.[2]

There have been several studies that have performed the s/z ratio in adults and children to establish the expectation for the given population or to assess change with treatment.[5−10] These studies have varied in the protocol used and in the s/z ratio data obtained. Pediatric and adult studies in participants with healthy voices have found ratios below 1 where /z/ was sustained longer than the /s/ or well above 1.2, approximating the values of those with disordered voices.[3−5,11] There have been other studies that have found an overlap between the s/z ratio values for normal and disordered voice,[8] considerably reducing the reliability and validity of s/z ratio as an assessment measure. This overlap may undermine the assumption that all pathologies affect glottal airflow during a sustained /z/ production more than for a sustained /s/ production.

The s/z ratio has been used in many studies on the disordered voice including vocal nodules or other mass lesions, essential tremor, presbylaryngeus, postmedialization thyroplasty, postintubation, and dysphonia secondary to Parkinson's disease.[6,7,12−14] A study by Trudeau and Forrest,[15] compared phonation volume and transglottal airflow between a maximally sustained /s/ and a maximally sustained /z/ in persons with a vocal fold mass lesion. They did not find a significant difference in the phonation volume or the airflow for the two consonants. While the lack of significance for phonation volume is expected, the lack of a

Accepted for publication February 27, 2019.

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Journal of Voice, Vol. 34, No. 4, pp. 533−538

0892-1997

https://doi.org/10.1016/j.jvoice.2019.02.014

significant difference in the airflow weakens the argument that in a disordered voice more airflow is required for /z/ resulting in a shorter maximum sustained duration than that for /s/. Contrary to the original rationale, the authors found a nonsignificant longer duration for /s/ than the /z/ in females, with a significantly greater difference in males. In another study by Treole and Trudeau,[16] there were no significant differences between the s/z ratio in participants with vocal nodules pretherapy and post-therapy. Eight out of 12 participants had an s/z ratio below 1.2. This study however, did not provide a comparison of the s/z ratio with other assessment data such as perceptual or acoustic analysis to compare the s/z ratio with amount of change in the voice with therapy. The s/z ratio has also been used as a screening tool after intubation to identify patients requiring a referral to the otolaryngologist for a potential laryngeal pathology.[14] Within 6 hours of extubation, 40% (13/32) of the patients had s/z ratios greater than 1.4, and after 24 hours, 19% (6/32) had a ratio greater than 1.4. These six individuals were diagnosed with a laryngeal pathology on a complete evaluation. The authors found that the s/z ratio is a screening tool with high sensitivity and specificity for laryngeal pathology when used 24 hours postextubation.

Vaca et al[13] used the s/z ratio as a part of their assessment battery for identifying glottal insufficiency in presbylaryngeus. They substituted the /z/ phoneme with the /e/ because their Spanish speaking participants demonstrated difficulty with the /z/ production. They compared the maximum sustained duration of /s/ to the maximum sustained duration of the /e/ sound and found a mean ratio of 1.13 with a range of 0.7−2.56. They found the ratio to have high specificity in this population and concluded that it is a good diagnostic test for the presbylaryngeus population.[13] However, the authors have not addressed if eliminating the articulation for the /z/ sound may have had an effect on the s/z ratio. There is also no data showing that the s/e ratio and s/z ratio are comparable.

The s/z ratio was initially described as a screening tool, but over the years, is often used as a diagnostic tool especially by clinicians with limited resources and/or experience working with patients with voice disorders. The s/z ratio, being a task of maximum performance, is limited by the variability between and within individuals from fatigue, a learning effect, and the natural difficulty when replicating a task. Instrumental measures of aerodynamics can provide objectivity in the measurement of laryngeal valving. Measures of airflow, subglottal pressure, and derived laryngeal resistance obtained using a pneumotachograph provide us with information regarding the valving ability of the vocal folds. Inverse filtering to obtain flow glottography and spirometry can also be used to obtain information about airflow. There have been numerous studies[17−22] that have used a pneumotachograph to establish expected values for normal and disordered voices under varying conditions of pitch and loudness.

The purpose of this study was to examine how the s/z ratio compared to instrumental measures of laryngeal valving and voicing efficiency and provide more information on its use as a diagnostic tool. The goal was to identify the nature of the relationship between the s/z ratio and vital capacity, maximum phonation time, vowel and sentence airflow measures, subglottal pressure, and laryngeal airway resistance (LAR).

METHODS

Participants

The participants included 15 male and 15 female adults with normal voice quality. The range and mean age for males was 22−37 years and 28.3 years respectively, and that for females was 22−41 years and 29.2 years. The participants had no significant medical history, had self-reported normal voice quality, no reported hearing loss, respiratory, or neurological illness. The clinician excluded any participant that had an abnormal voice quality perceptually during recruitment.

Procedure

Participants were instructed to perform all tasks at comfortable pitch and loudness. In the event that their production was perceptually at a different pitch and loudness level than the conversational level, participants were asked to repeat the trial. For the calculation of the s/z ratio, participants were asked to sustain the /s/ sound for as long as possible followed by the /z/ sound for as long as possible, to complete one trial. Duration of the sustained sound was measured using a stopwatch. All participants performed three trials of the sustained /s/ and sustained /z/. The number of trials was limited to three to keep it consistent with standard clinical practice. The s/z ratio was then calculated for each trial and the average s/z ratio was used for statistical analyses.

The Phonatory Aerodynamic System (PAS) Model 6600 (KayPENTAX Corp, Lincoln Park, New Jersy) was used to obtain objective aerodynamic measures. The system was calibrated as described in the PAS manual prior to beginning data collection.[23] Participants were asked to wear the facemask attached to the pneumotachograph and maintain a tight seal during the tasks. Participants completed three trials of the PAS protocols for vital capacity, mean airflow during comfortable sustained phonation and running speech and; voicing efficiency for subglottal pressure and derived LAR.

During the vital capacity task, participants were asked to take a deep breath, place the facemask firmly on their face, followed by a maximum exhalation. For the maximum phonation task, participants took a deep breath, placed the facemask firmly on their face, and sustained /a/ for as long as possible. During the running speech task, participants were asked to place the facemask firmly on their face and read the first two sentences of the Rainbow Passage. The measurement of airflow rate during connected speech was obtained as a ratio of the total expiratory volume during voicing to the duration of voicing. Care was taken to

exclude all nonspeech segments based on corresponding pitch and intensity tracings.[20,22] The voicing efficiency task required the participants to place the oral pressure tube attached to the pneumotachograph in the mouth, just behind the teeth, taking care to not hold the tube under the tongue or bite down on it, and place the facemask firmly on the face. Participants produced seven iterations of /pa/ in one breath, at comfortable pitch and loudness. This task provided us with measures of estimated subglottal pressure and derived LAR.

Data analyses

Statistical analyses were performed using SPSS 25.0.[24] Descriptive data on the means and standard deviations of the variables examined were calculated. Pearson's Product Moment Correlation was applied to compare the s/z ratio to objective aerodynamic measures and identify the nature of the relationship between these variables. A univariate analysis of variance was performed to examine for differences between sexes for all the variables and between the s/z ratios for each of the trials. Coefficients of variance were also calculated for trials 1, 2, and 3 of the s/z ratios to measure variability within the trial.

TABLE 1.
Mean, Standard Deviations (S.D.) and Range for s/z Ratio, Vital Capacity (VC), Maximum Phonation Rime (MPT), Vowel and Sentence Airflow Rate, Subglottal Pressure (Ps) and LAR (LAR)

	Sex	Mean	S.D.	Range
s/z ratio	Female	1.09	0.25	0.87–1.57
	Male	1.07	0.37	0.59–2.13
VC (L)	Female	3.66	0.58	2.9–4.94
	Male	4.45	1.15	1.93–5.95
MPT (s)	Female	18.92	4.97	10.51–27.89
	Male	24.16	6.14	12.08–29.99
Vowel airflow rate (L/s)	Female	0.17	0.06	0.06–0.27
	Male	0.14	0.10	0.02–0.21
Sent. airflow rate (L/s)	Female	0.15	0.05	0.071–0.27
	Male	0.15	0.07	0.021–0.25
Ps (cmH_2O)	Female	5.84	1.95	2.45–8.98
	Male	6.90	2.53	3.43–12.18
LAR ($cmH_2O/L/s$)	Female	50.43	28.83	10.15–120.24
	Male	55.45	60.64	8.14–248.47

RESULTS

Means and standard deviations for the s/z ratio, vital capacity, maximum phonation time, vowel and sentence airflow, subglottal pressure, and LAR are provided in Table 1.

Data from the Pearson's correlation (Table 2) indicated a moderate negative relationship ($r = -0.632$, $P < 0.05$) between the s/z ratio and LAR in females, and a moderate negative relationship ($r = -0.593$, $P < 0.05$) between sentence airflow and the s/z ratio in males. There were no other significant relationships between the s/z ratio and the instrumental measures when collapsed across sex or when grouped for males and females. Scatterplots illustrating the relationship between the s/z ratio and the instrumental measures are provided in Figures 1a–d and 2a–c.

There were significant differences ($P < 0.05$) in the values between males and females for measures of vital capacity ($F = 5.758$, $df = 1$, $P = 0.023$) and maximum phonation time ($F = 6.607$, $df = 1$, $P = 0.016$). There were no significant differences ($P < 0.05$) for the s/z ratio, sentence airflow, subglottal pressure, and LAR. There were also no significant differences ($P < 0.05$) between the first, second, and third trials of the s/z ratio. The coefficient of variance was calculated to assess for variability within each trail. The coefficient of variance for trial 1 was 33.33%, for trial 2 was 46.90%, and for trial 3 was 22.54%.

DISCUSSION

The use of the s/z ratio in clinical voice assessment has been debated over many years, yet there is limited evidence on its accuracy and reliability. This measure has been described as both a screening tool and a diagnostic tool. While it has been accepted as a screening tool, Trudeau and Forrest discouraged its use for screening due to the high rate of false negatives.[15] The diagnostic use of the ratio is still in question. The s/z ratio was developed as a measure of laryngeal valving, but there have been no comparisons made to other measures of laryngeal valving that are not maximum performance tasks, and thus less dependent on patient performance. It is popular due to the minimal costs and training

TABLE 2.
Pearson's Correlation (r) for the s/z Ratio with Instrumental Measures of Aerodynamics – Vital Capacity (VC), Sentence Airflow Rate, Subglottal Pressure (Ps) and LAR (LAR). Correlations Significant at $P < 0.05$ are Indicated by a (*).

			s/z Ratio	VC	MPT	Sent. Airflow Rate	Ps	LAR
Female	s/z ratio	r	1.00	0.100	−0.264	0.160	0.175	−0.632*
		Sig		0.724	0.341	0.570	0.533	0.012
Male	s/z ratio	r	1.00	−0.457	−0.101	−0.593*	−0.017	0.181
		Sig		0.087	0.720	0.020	0.952	0.520

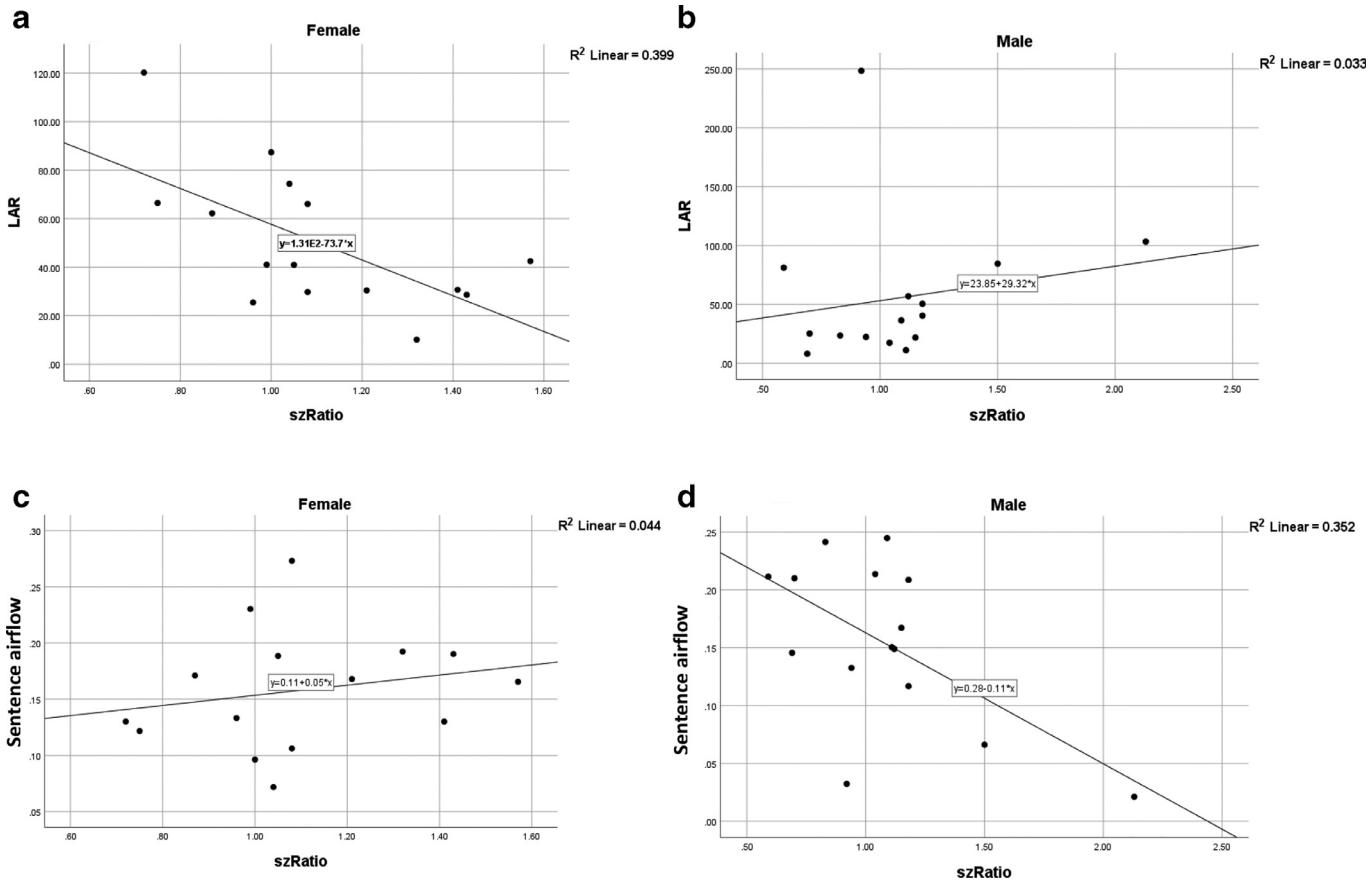

FIGURE 1. (a–d) Scatterplots and coefficients of determination (r^2) for s/z ratio measurements illustrating relationships between laryngeal airway resistance (LAR) (a and b), and sentence airflow in females and males (c and d).

involved in obtaining the measure. The goal of this study was to compare the s/z ratio to instrumental measures of aerodynamics to investigate if the s/z ratio was reliable as a measure of laryngeal valving.

The data obtained for the aerodynamic measures using the PAS are in keeping with the normative data for the PAS reported in the study by Zraick et al.[17,25] There is a wide range for these aerodynamic measurements in the current study and in prior studies,[17,25,26] possibly due to the different instruments used, individual strategies, and physical variability within people. Fifteen males and 15 females with normal voice quality performed similarly on the s/z ratio tasks with no significant differences in their ratios. Even without significant differences between sexes, the s/z ratios in females had a moderate negative correlation with LAR that is, when s/z ratio increased, LAR was reduced and vice versa. This seems appropriate considering the s/z ratio would be high if the /z/ cannot be sustained as long as the /s/ when there is a glottal gap and thus reduced laryngeal resistance. This relationship was not seen in males. Women have been shown to have more variability in their LAR[27] than men. In the absence of a vocal pathology, the differences in LAR can be attributed to the presence of a normal posterior glottal gap in females and/or use of different laryngeal valving strategies.[27] It can be hypothesized that this relationship may be stronger in persons with glottal incompetence.

There was no significant difference between males and females for the sentence airflow rate. The men, however, demonstrated a moderate negative correlation between sentence airflow rate and the s/z ratio that is, as the s/z ratio increased, sentence airflow rate decreased. The sentence airflow rate was measured on the first two sentences of the Rainbow passage. While this finding is statistically significant, it is unclear if it is clinically significant. With an increased s/z ratio and decreased glottal competency, one would expect an increase in airflow rate with reduced resistance to the air. It is possible that some participants used multiple breaths to produce these two sentences while others were able to do so within a single breath affecting the airflow rate. On reviewing the data, male participants were found to produce these two sentences using 1–3 breaths. A majority of the participants (10/15) used the same number of breaths for all three trials but there was no relationship found between the average sentence airflow rate and the average number of breaths for the task.

This study is limited by the absence of participants with a laryngeal pathology. A comparison of the same variables in the disordered voice group would provide more insight on the applicability of the s/z ratio. For the connected

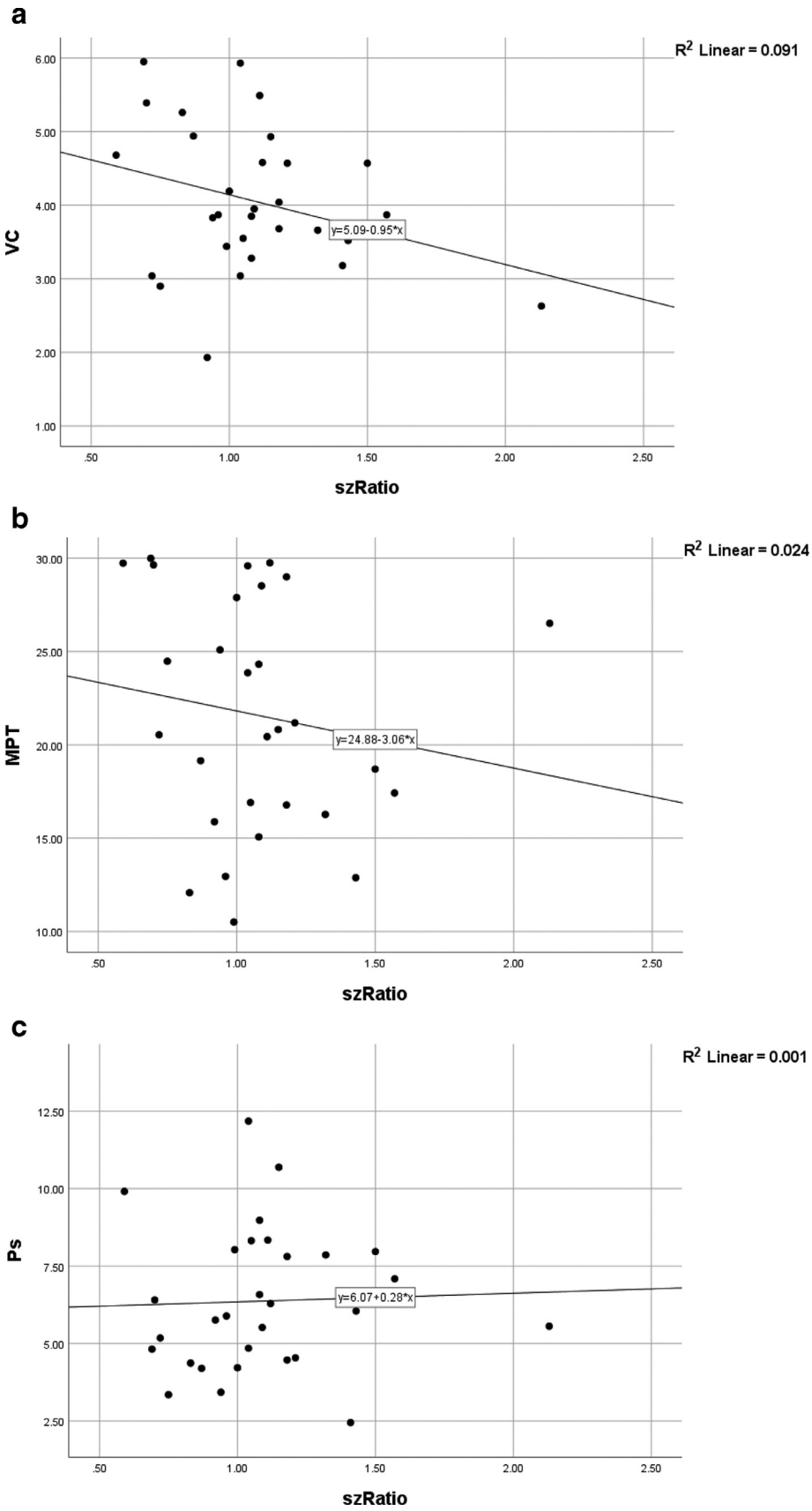

FIGURE 2. (a–c) Scatterplots and coefficients of determination (r^2) for s/z ratio measurements illustrating relationships between vital capacity (VC) (a), maximum phonation time (MPT) (b), and subglottal pressure (Ps) (c).

speech task, the PAS mask restricted mandibular movement and speech production may have been less natural. Overall however, the s/z ratio has shown to have a moderate correlation with only a limited number of instrumental and objective measures of laryngeal valving in this study-LAR in females and sentence airflow rate in males. The evidence of the accuracy of the s/z ratio as a diagnostic measure of laryngeal valving is not clear and hence the s/z ratio should be used in combination with other instrumental measures of laryngeal aerodynamics for a better representation of aerodynamic functioning. Clinicians that do not have the resources for, or access to a pneumotachograph for the instrumental measures used in this study are encouraged to explore other low cost options such as the measures obtained with a spirometer and derived measures of phonation quotient (ratio of vital capacity, which can be obtained with a spirometer, to maximum phonation time).[28–31] As always, clinicians are encouraged to perform a thorough evaluation that includes auditory-perceptual and acoustic analyses with visual imaging of the vocal folds and patient self-rating along with aerodynamic assessment to obtain a holistic understanding of the voice disorder. Future studies will replicate this protocol in laryngeal pathologies with varying physiological underpinnings for similarities and differences in persons with and without voice disorders.

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