The Relationship Between the Aerodynamic Parameters of Voice and Perceptual Evaluation in the Iranian Population With or Without Voice Disorders

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Summary: Objectives. Aerodynamic evaluations can provide useful information about the interaction between the respiratory and the phonation systems. The present study was conducted to investigate the relationship of maximum phonation time (MPT), vital capacity (VC), and phonation quotient (PQ) with perceptual evaluation in different types of dysphonia. The relationship between these parameters and the type of dysphonia was also examined.

Materials and Methods. The study participants consisted of 300 individuals with different types of dysphonia (104 women and 196 men) and 100 healthy samples (63 women and 37 men). A professional speech-language pathologist conducted the perceptual evaluation based on the G (grade) component of the GRBAS scale, which stands for grade, roughness, breathiness, asthenia, and strain. VC was measured using a spirometer and MPT using a stopwatch. PQ was calculated as the ratio of VC to MPT.

Results. The difference between the mean ± standard deviation of PQ, VC, and MPT were found to be significant at all the four degrees of dysphonia severity (P < 0.001). There was a significant difference in mean MPT and VC between the genders (P < 0.001), but no significant gender differences were observed in terms of the mean PQ (P = 0.346). The study participants were classified into four groups, including the organic dysphonia group, neurologic dysphonia and functional dysphonia groups, and the normal group; the study variables measured were found to be significantly different between all the four groups (P < 0.001).

Conclusion. As MPT and PQ were correlated with the perceptual G (grade) and differentiated dysphonic from healthy individuals, clinicians are recommended to take account of them in their instrumental evaluations.

Key Words: Phonation quotient–Vital capacity–Maximum phonation time–Dysphonia–GRBAS.

INTRODUCTION

Phonation or the generation of audible sound energy is caused by muscular and aerodynamic activities that affect the vocal cords. Sufficient airflow during exhalation is a prerequisite for efficient vibration of the vocal cords while producing voice. Laryngeal injuries and physiological imbalance in the subsystems responsible for voice production change aerodynamic flow and pressure. Therefore, it is of special importance to evaluate the aerodynamic status in the study of physiology and pathophysiology of voice production.

Boone et al. divides dysphonia into three general categories: organic, functional, and neurologic dysphonia. The severity of dysphonia is often measured by perceptual judgments and using instrumental measurements. The objective assessment of voice is still a subject of debate in daily clinical practices. The perceptual evaluation of voice is valued by physicians and researchers as a gold standard in recording the severity of voice disorders. The GRBAS scale is currently being widely used as a gold standard in recording the severity of voice disorders.

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Key Words: Phonation quotient–Vital capacity–Maximum phonation time–Dysphonia–GRBAS.
evaluation and is also the most common aerodynamic measure for assessing glottal sufficiency.\textsuperscript{17} MPT has been used in different studies for voice evaluation,\textsuperscript{6} the investigation of glottal sufficiency, differentiation between normal and dysphonic voice,\textsuperscript{18} and examining the effects of age and gender.\textsuperscript{19} The reliability of MPT was reported as 0.987 with five test-retests.\textsuperscript{20} This tool proved to be hypersensitive to the impact of learning and fatigue. The potential bias can be reduced by measuring the average phonation airflow or PQ.\textsuperscript{21} PQ is the ratio of VC to MPT and is expressed in mL/s\textsuperscript{22} and is used as a tool for measuring glottal sufficiency, differentiating between damaged and normal voice, and recording treatment results.\textsuperscript{18,23,24} VC is the difference in the volume of air in the mouth between the deepest inhalation and a complete exhalation and is measured with a spirometer.\textsuperscript{21}

In clinical practices and research, aerodynamic measurement is often taken to refer to MPT,\textsuperscript{25,26} PQ,\textsuperscript{25,26} the mean flow rate, and the subglottal pressure.\textsuperscript{27,28} The selection of aerodynamic parameters is therefore useful for differentiating normal from dysphonic voices. The airflow rate can be measured to help monitor the effects of the treatments when glottal performance is compared before and after surgical interventions or before and after the use of voice therapy techniques.\textsuperscript{29} For instance, to compare the effectiveness of a treatment intervention, the average phonation airflow is recommended to be measured before and after the intervention using a single method.\textsuperscript{26} MPT is used for externalizing the degree of dysphonia and for determining the effects of voice therapy.\textsuperscript{30} To date, many studies have been conducted on aerodynamic parameters; however, the majority of them have examined only certain disorders or limited populations.

In one study, Cantarella et al used logistic regression analysis to show that only 3 of the 12 variables examined are competent for discriminating dysphonic from normal samples. MPT was one of the three confirmed variables. In the mentioned study MPT was found to be a sensitive indicator of dysphonia that can differentiate between pathologic and normal voices.\textsuperscript{14} Yu et al conducted a study to determine the clinical value of the multiparametric objective voice evaluation protocol and compared aerodynamic and acoustic parameters through the perceptual analysis of continuous speech. The results showed that a non-linear combination of six parameters matched the evaluators’ perceptual classification by 86% and a high correlation was thus obtained between MPT and perceptual-auditory judgments.\textsuperscript{31}

Piccirillo et al used multivariate logistic regression to determine the objective voice parameters used for describing the severity of dysphonia and found that 4 of the 14 study indices can discriminate between normal and dysphonic voice, and MPT was one of the confirmed indices.\textsuperscript{31} Wuyts et al conducted a study that led to the development of the dysphonia severity index and found that MPT is an effective parameter for predicting the perceptual severity of dysphonia. They also found in their study that VC and PQ were significantly correlated with the perceptual G (grade); however, MPT was the only parameter that was approved for the final model.\textsuperscript{6} MPT is therefore a phonation control marker. MPT, VC, and average phonation airflow are among the aerodynamic parameters of voice assessment that are most convenient in terms of time requirements and cost-effectiveness.

Unfortunately, there are few data demonstrating the aerodynamic results of a wide range of voice disorders in Asian people. Given the ethnic differences, and consequently anatomic and physiological differences between Asian and European or American people, the present study was conducted to explore the relationship of MPT, VC, and PQ with the G (grade) parameter of perceptual GRBAS scale in the Iranian population with or without voice disorders.

**MATERIALS AND METHODS**

The ethical principles of the Declaration of Helsinki were followed throughout the study. Moreover, the ethics committee of Social Welfare and Rehabilitation Sciences University approved the study protocol. Subjects were completely aware of the study’s content and provided consent before participating.

**Study participants**

The study participants consisted of 300 willing patients with different types of dysphonia (104 women and 196 men) presenting to the Ear, Nose and Throat Clinic of Amiralam Hospital in Tehran, Iran, between November 2014 and June 2015, and a total of 100 healthy samples without dysphonia (63 women and 37 men). The samples without dysphonia had no history of laryngeal injuries or use of larynx damaging substances and did not have a cold or allergies at the time of sampling. None of the subjects had a history of lung disease, and they all gave their full consent for participation in this analytical cross-sectional study and spoke Persian. The subjects were at an age range of 18–65 with a mean ± standard deviation (M ± SD) of 45.3 ± 12.9 in the dysphonic and 40.3 ± 14.1 in the healthy group.

**Perceptual voice evaluation**

A digital voice recorder, SONY ICD-UX530, was used to record each subject’s voice sample through an interview discussing their voice condition. The recorded voice was then presented to a professional speech-language pathologist with more than 15 years of experience in the evaluation and treatment of voice disorders. The G (grade) parameter of the GRBAS scale was scored for each participant based on the total hoarseness in his speech sample. The participants were divided into four groups, including the normal, mild dysphonia, moderate dysphonia, and severe dysphonia groups, based on the perceptual judgments and their G (grade) on the GRBAS scale.

**Aerodynamic measures**

VC was recorded for each participant using the Fukuda Sangyo St-250 spiroanalyzer. The participants were asked to inhale deeply and then blow into the spirometer as lengthily and strongly as possible. This experiment was repeated three times and the maximum VC was recorded for each participant. To measure the MPT, the participants were asked to pronounce the vowel /a/ and prolong it as long as possible and to repeat this task three times, and the longest MPT was used for analyses. The MPT was then recorded for each participant. The PQ was calculated by dividing the maximum VC by the MPT.
### Statistical analyses

The one-way analysis of variance was used to compare mean values of PQ, VC, and MPT variables in the four G groups, mean values of the variables in the four groups, including normal, organic dysphonia, functional dysphonia, and neurologic dysphonia, and mean values of VC in the age groups. The least significant difference method was used to make pairwise comparisons in cases of significant differences between mean values. To compare the two genders in terms of mean values of each variable, the normal distribution of that variable in males and females was examined using one-sample Kolmogorov-Smirnov test, and then, mean values were compared using $t$ test. The multivariate analysis was performed to compare mean values of PQ, VC, and MPT variables in males and females simultaneously.

### RESULTS

Table 1 shows participants’ distribution in terms of their severity of dysphonia grade, as 93 (23.25%) of the samples were given G3, 103 (25.75%) G2, 104 (26%) G1, and 100 (25%) G0. For example, 24 (6%) of the patients with carcinoma were given G3, 12 (3%) G2 and 4 (1%) G1.

The M ± SD of MPT in men was 15.6 ± 5.6 in the normal group, 12.0 ± 4.9 in the mild dysphonia group, 10.2 ± 4.7 in the moderate dysphonia group, and 8.1 ± 5.1 in the severe dysphonia group, indicating a significant difference in MPT between the four degrees of dysphonia severity ($P < 0.001$). Also, the M ± SD of MPT in women was 12.0 ± 5.2 in the normal group, 9.6 ± 3.9 in the mild dysphonia group, 8.3 ± 3.5 in the moderate dysphonia group, and 7.3 ± 5.5 in the severe dysphonia group, indicating a significant difference in MPT between the four degrees of dysphonia severity ($P < 0.001$). Similarly, the M ± SD of VC in men was 3864 ± 787 in the normal group, 3955 ± 842 in the mild dysphonia group, 3811 ± 747 in the moderate dysphonia group and 3282 ± 852 in the severe dysphonia group in men, indicating a significant difference in VC between the four degrees of dysphonia severity ($P < 0.001$), and the M ± SD of VC in women was 3457 ± 745 in the normal group, 3076 ± 638 in the mild dysphonia group, 2931 ± 707 in the moderate dysphonia group, and 2933 ± 703 in the severe dysphonia group in women, indicating a significant difference in VC between the four degrees of dysphonia severity ($P < 0.001$). The M ± SD of PQ in men was 278 ± 119 in the normal group, 378 ± 178 in the mild dysphonia group, 448 ± 201 in the moderate dysphonia group, and 542 ± 309 in the severe dysphonia group, indicating a significant difference in PQ between the four degrees of dysphonia severity ($P < 0.001$), and the M ± SD of PQ in women was 331 ± 155 in the normal group, 387 ± 203 in the mild dysphonia group, 436 ± 255 in the moderate dysphonia group, and 582 ± 352 in the severe dysphonia group, indicating a significant difference in PQ between the four degrees of dysphonia severity ($P < 0.001$) (Table 2).

A pairwise comparison of the findings was conducted through the least significant difference post hoc test. The results of the post hoc test showed that mean MPT in males significantly differed from one group to another, and mean MPT in females significantly differed from that in other groups only in the normal group ($P < 0.05$). Mean VC in men significantly differed from that in other groups only in the group with severe dysphonia. In other words, no significant differences were observed in the normal, mild dysphonia, and moderate dysphonia groups in terms of the mean VC ($P > 0.05$) (Table 2). However, mean VC in females significantly differed from that in other groups only in the normal group ($P < 0.05$). Mean PQ in males did not significantly differ from that in the group with moderate dysphonia only in the group with mild dysphonia, but significantly differed from one another in other groups ($P < 0.05$). Mean PQ in females was not significantly different between the normal group and the group with mild dysphonia and between the group with mild dysphonia and the group with moderate dysphonia, but other groups differed significantly from one another in this regard ($P < 0.05$) (Table 2).

The significant difference of means between the groups based on their G (grade) classification in the perceptual scale shows that these variables are correlated with the G (grade) parameter. The MPT was found to be positively and significantly correlated with the VC ($r = 0.42$).
The participants were divided into three age groups of 18–34 years, 35–49 years, and 50–65 years to examine the effect of age on VC values. The data in the normal group and the groups with dysphonia were analyzed separately. The results showed that mean VC did not significantly differ from one age group to another age group either in the normal group or in the groups with dysphonia ($P > 0.05$) (Table 3).

As shown in Table 4, no significant differences were observed in the mean PQ between the genders ($P = 0.346$), whereas the mean MPT and VC were found to differ significantly by gender ($P < 0.001$). The interaction between gender and the perceptual G (grade) was investigated in terms of PQ, VC, and MPT. Gender was found to have an interaction with the perceptual G (grade) in terms of VC. A separate analysis was therefore conducted in each gender, showing that the mean VC is significantly different between the four groups in both women and men ($P < 0.001$).

The study variables were examined between the normal group, the organic dysphonia group, the neurologic dysphonia group, and the functional dysphonia group. The mean MPT and PQ were significantly different between the normal group and the other three groups with dysphonia ($P < 0.001$); however, these variables were not significantly different between the three dysphonia groups themselves. The mean VC was also significantly different between the group with neurologic dysphonia and the other three groups ($P < 0.05$); however, the other three groups showed no significant differences in terms of the mean VC (Table 5).

**DISCUSSION**

It is a proven fact today that voice is a multidimensional phenomenon, and many researchers have come to the conclusion that a single quantitative measurement cannot determine the severity of dysphonia. Different parameters are therefore taken into account in different populations to investigate voice disorders. The main purpose of the present study was to examine the relationship of MPT, VC, and PQ with the perceptual G (grade) in the GRBAS scale.

In both males and females, the analysis of the results showed a statistically significant difference among the four groups, ie, the G0, the G1, the G2, and the G3 in terms of MPT. In males, the post hoc test showed that the mean MPT is significantly different between all the groups. The post hoc test in females showed that mean MPT significantly differed from that in the groups with dysphonia only in the normal group, and the groups with
dysphonia were not significantly different from one another in this regard. It seems that the females’ lower MPT than males’ is the reason for the insignificant differences among groups with dysphonia and the significant difference between normal group and the groups with dysphonia, whereas the effect of the severity of dysphonia in MPT for males is more considerable because of their higher MPT.

The findings suggest that MPT is associated with the G (grade) parameter in the perceptual scale and that the higher is G (grade), the lower drops MPT. Changes in the perceptual G (grade) in the GRBAS scale are thus expected to alter the MPT as well. Therefore, aerodynamic parameters may be used to assess voice when acoustic instruments are not available.

This finding is consistent with the results of studies conducted by Yu et al and Wuyts et al, who found a moderate to high correlation between the MPT and the G (grade) in the GRBAS scale between the different groups examined.6,8 The values Yu et al reported in their study for the G0 and G1 groups were higher than the values obtained in the present study; however, compared with the present study, the values they reported were lower for the G3 group and similar for the G2 group. Along with some other components, MPT can differentiate between different degrees of hoarseness. Different statistical analyses conducted in the literature also found MPT to be an effective factor for determining the degree of dysphonia.6,8

In males, significant difference was observed in the mean VC between the G3 group and the other three groups; however, G0, G1, and G2 were not significantly different from each other in terms of this variable. In other words, the mean VC was only significantly different from the other groups in the severe dysphonia group. However, females’ VC differed significantly from that in other groups only in the normal group. Regarding the differences observed between the group with severe dysphonia and other groups in males or between the normal group and the groups with dysphonia in females, it seems that VC further correlates with the total quality of voice only under normal conditions or severe dysphonia, and slightly correlates with the quality of voice in the case of mild and moderate dysphonia. These results should be further investigated.

The post hoc test showed the mean PQ to be significantly different between all the four groups. Although there was no significant difference between the group with mild dysphonia

<table>
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<tr>
<th>TABLE 4. Multivariate Comparison of the Means of PQ, VC, and MPT in Males and Females</th>
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<th>MS</th>
<th>F</th>
<th>P Value</th>
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Abbreviations: df, degree of freedom; F, F statistics.

<table>
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<tr>
<th>TABLE 5. Comparison of the Mean PQ, VC, and MPT in the Normal, Neurologic Dysphonia, Functional Dysphonia, and Organic Dysphonia Groups</th>
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<tr>
<td>MPT (s)</td>
</tr>
<tr>
<td>VC (mL)</td>
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<td>PQ (mL/s)</td>
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Abbreviations: No, normal voice; Ne, neurologic; Fu, functional; Or, organic.
and the group with moderate dysphonia in males, and there was no significant difference between the normal group and the group with mild dysphonia and between the group with mild dysphonia and the group with moderate dysphonia in females, there was a correlation between PQ and perceptual G score. These results are somewhat consistent with the results of the study by Wuyts et al, who found the VC and PQ to be weakly correlated with the G (grade) component of the GRBAS. 6

A comparison of MPT between the healthy and the dysphonic subjects showed that the mean MPT is significantly higher in the normal group than in the dysphonic group. The mean MPT in the dysphonic group was 10.1 for the male and 8.5 for the female participants; in the normal group, it was 15.6 for the male and 12.0 for the female participants. Pathologic conditions of the larynx thus reduce MPT. These findings are consistent with the findings of previous studies. 18,22 The MPT obtained in the present study is lower than the value obtained in other studies. A multiparametric evaluation of the degree of dysphonia reported a mean MPT of 15.2 in the dysphonic subjects and 22.9 in the controls. 32 Another study reported the mean MPT as 24.7 in healthy people. 33 A study conducted to develop a multiparametric model found a mean MPT of 12.4 in the dysphonic subjects and 18.9 in the controls, 6 which are higher than the figures obtained in the present study. A study conducted in an Indian population, however, found the mean MPT to be 15.7, 34 which is closely similar to the values obtained in the present study. Other studies also reported a lower MPT in Asian populations. 35 These cases show that MPT is generally lower in Iran than that reported from non-Asian populations both in normal people and in people with dysphonia.

The findings suggest a moderate correlation between MPT and VC; that is, the higher is VC, the higher becomes MPT. In contrast to the present findings, Solomon et al found no relationships between VC and MPT 16; nevertheless, the majority of studies confirm the relationship between MPT and VC. The higher lung volume and the better airflow rate increase the phonation duration. 37,38 According to Lewis et al, VC is linked to the prolongation of the vowel /a/. 39 Given that the varieties of dysphonia were examined in this study, it seems that the degree of this correlation may vary in different voice disorders or in different degrees of dysphonia.

In this study, the mean VC did not significantly differ from one age group to another. These results conform to those of the study by Sharma and Goodwin. They concluded that significant changes occur in the pulmonary function with an increase in age, which results in a decrease in pulmonary compliance that is more significant after the age of 70. 40 Considering that the age range in this study was up to 65 years, the results conform. Therefore, differences in VC are expected to be detectable with an increase in the age range.

A comparison of the effect of gender on MPT, VC, and PQ showed that the mean MPT and VC differ significantly between the genders; that is, MPT and VC were higher in men than in women, whether in the normal group or the dysphonic group. Hirano also reported a significant difference between the genders in terms of MPT, which is consistent with the results of the present study 9; in this study, no significant differences were observed in terms of PQ between the genders. These results are consistent with the results obtained by Morssonne et al, 41 although their study population consisted only of older people. It seems that the reason for the fact that the MPT and VC in one gender differed from those in another gender is the anatomic and physiological differences between the two genders.

A significant difference was observed only between the normal group and all the other three dysphonic groups in terms of MPT and PQ, and the dysphonic groups were not significantly different from each other with respect to these two variables. A study conducted to determine the aerodynamic and acoustic indices differentiating organic dysphonia from normal voice found that MPT is a factor that can discriminate dysphonic from healthy people, 14 which is consistent with the results obtained in the present study. Other studies, such as those by Iwata and von Leden, also found PQ to be different between the normal group and the three dysphonia groups examined; however, they found no differences between the dysphonia groups themselves. 42 The present study observed no significant differences in terms of VC between the normal and the dysphonia groups and only found the neurologic group to be different from the other groups in terms of this variable. It seems that neurologic disorders affected VC values because they did not affect the tissue of vocal cords like other disorders and influenced the neuromuscular function of the vocal cords. There is a lack of studies conducted to examine VC in different types of dysphonia and to compare it with healthy controls. Nevertheless, the general findings on this subject are consistent with the theory that VC and voice quality are not positively linked. 26 The different VC observed in the neurologic dysphonia group in the present study necessitates further studies on the subject.

CONCLUSION

The present study explored the relationship of variables including MPT, VC, and PQ with the perceptual G (grade) in the GRBAS scale as a gold standard. These variables are associated with the perceived degree of dysphonia, and MPT and PQ can also be used as measures that have significant relationships with the perceptual assessment of the overall degree of hoarseness. Because MPT and PQ were different between the healthy and the dysphonic samples, clinicians are recommended to take account of them in their instrumental evaluations. Clinical evaluations should also take account of the existing gender differences in aerodynamic measurements.

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REFERENCES

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Mahshid Aghajanzadeh et al. Aerodynamic Evaluations in the Iranian Population


