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Examining the Relationship between GRBAS Ratings and Acoustic, Aerodynamic and Self-Perceptual Voice Measures in Adults with Voice Disorders

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Abstract:

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To determine if auditory-perceptual voice ratings performed using the GRBAS scale correlate with acoustic and aerodynamic measures of voice. A secondary aim was to examine the relationship between GRBAS ratings and patient-reported quality of life measures.

Methods

GRBAS ratings, acoustic, aerodynamic and patient-reported quality of life measures were collected from the University of Wisconsin Madison Voice and Swallow Outcomes Database for 508 adults with voice disorders. Acoustic measures included noise to harmonic ratio, jitter%, shimmer%, highest frequency of vocal range, lowest frequency of vocal range, maximum phonation time and dysphonia severity index (DSI). Aerodynamic measures included phonation threshold pressure, subglottal pressure, mean transglottal airflow and aerodynamic resistance. Patient-reported quality of life measures included the Vocal Handicap Index (VHI) and Glottal Function Index (GFI).

Results

GRBAS ratings were significantly correlated with several acoustic and aerodynamic measures, VHI and GFI. The strongest significant correlations for overall voice quality were observed between GRBAS ratings of overall voice quality, and perturbation measures (jitter% r^2 =.24, shimmer% r^2 =.30, NHR r^2 =.24), DSI (r^2 =.29), and vocal frequency range (r^2 =.36). GRBAS ratings of over-all voice quality were also significantly correlated with transglottal airflow (r^2 =.15) and subglottal pressure (r^2 =.15), as well as both VHI (r^2 =.23) and GFI scores (r^2 =.20).

Conclusions

Although GRBAS ratings were significantly correlated with multiple objective voice and patient related quality of life measures, r^2 values were in low to medium range across all correlations. These findings support the need for multiple voice measures when performing voice evaluations as no single voice measure explained high amounts of variation in voice quality as measured by the GRBAS scale.

Examining the Relationship between GRBAS Ratings and Acoustic, Aerodynamic and Self-Perceptual Voice Measures in Adults with Voice Disorders

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Conclusions: Although GRBAS ratings were significantly correlated with multiple objective voice and patient related quality of life measures, r^2 values were in low to medium range across all correlations. These findings support the need for multiple voice measures when performing voice evaluations as no single voice measure explained high amounts of variation in voice quality as measured by the GRBAS scale.

Introduction

Current best practice dictates that clinical voice evaluations should include multiple types of voice measures[1,2] including objective measures (i.e., acoustic or aerodynamic), patient-related quality of life measures, and auditory-perceptual assessment. Acoustic and aerodynamic voice measures are important as they describe laryngeal function and efficiency,[3–5] and patient reported quality of life measures are critical because they describe patient perceptions of voice problems which, in turn, drive treatment adherence.[6–8] Auditory-perceptual analysis of voice quality is vital as it allows clinicians to quantify the functional impact of voice disorders on voice quality.[9–12] Further, auditory-perceptual voice assessment also allows clinicians to measure and capture voice quality in a manner that no single acoustic and/or aerodynamic measure has been able to do. Performing auditory-perceptual voice assessments in a consistent manner is difficult, however, as clinician ratings can be influenced by multiple factors including rater experience, profession, and rating stimuli.[12–15] For this reason, rating scales such as the Grade, Roughness, Breathiness, Asthenia and Strain (GRBAS) scale have been developed in an attempt to standardize voice assessment.[16] The GRBAS scale is commonly used, easy to perform, and is validated against other voice assessment scales such as the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V).[17,18] However, the extent to which GRBAS ratings correlate with objective and patient-reported quality of life measures is not well understood. This is concerning because auditory-perceptual, acoustic, aerodynamic, and patient-reported voice measures are used in concert, even though they quantify different constructs. For example, while auditory-perceptual measures quantify voice quality from a functional perspective,[17] acoustic measures describe sound wave characteristics,[19] aerodynamics measure aspects of laryngeal physiology[4] and patient-reported measures describe impact of vocal pathology on daily life.[20,21] As such, understanding the relationship between these constructs informs voice evaluation. Ideally, GRBAS ratings should reflect other types of voice measures as they are often used to assess therapeutic outcomes and measure patient progress.

The relationship between GRBAS ratings and acoustic measures of voice has been the subject of some initial investigation. Bhuta and colleagues examined the relationship between GRBAS ratings and 19 acoustic measures produced by the Multi-Dimensional Voice Program (MDVP) in 37 dysphonic adults.[9] Only limited correlations between GRBAS ratings and acoustic measures were reported. Specifically, overall voice quality was only correlated with noise-to-harmonic ratio (NHR), voice turbulence index and soft phonation index.[9] R^2 values, however, were low for all correlations mentioned above, indicating that GRBAS ratings explained only a small portion of the variation in these acoustic measures. Although these results constitute an important first step, further work is needed to understand the relationship between acoustic measures and GRBAS ratings. In particular, examining this relationship with a larger sample size is crucial.

Interestingly, the relationship between GRBAS ratings and aerodynamic measures in adults has not been examined in the literature. This is surprising given that aerodynamic measures quantify aspects of laryngeal physiology which should, in theory, have an impact of voice quality – particularly on ratings of breathiness.

Initial research has also investigated the relationship between GRBAS scores and patient related quality of life scales. This is important as clinicians must not only consider their own perceptions of voice outcomes but should also be cognizant of patient perception of those outcomes in order to ensure patient compliance. Karnell and colleagues examined the relationship between the GRBAS scale and the Voice Related Quality of Life and the IOWA Patient's Voice Index.[12] The authors found these patient-based measures were positively correlated, but the relationship was weak. A study has also investigated the relationship between the Vocal Handicap Index (VHI) and GRBAS scale. The VHI is a commonly utilized tool to assess patient perceived voice outcomes. This scale separates patient perceptions into three categories; functional, physical and emotional, which allows for specific understanding of patient experience.[20] Although Sabir and colleagues reported that overall grade of voice quality was associated with the VHI in children,[22] additional research is needed to determine if this relationship holds in adults. The Glottal Function Index (GFI) is another patient related quality of life scale which has recently been described in the literature. The GFI consists of only four questions probing vocal effort, fatigue pain, and quality and has been shown to be efficient, easy to administer, and reliable.[21] Considering that the VHI is widely used and the GFI is an efficient option for clinicians, additional investigation of the relationship between GRBAS scores and both the VHI and GFI is warranted.

This study sought to address the gap in our understanding of the relationship between objective and patient related quality of life measures. In order to illustrate the extent to which GRBAS ratings reflect different aspects of laryngeal physiology, we examined the relationship between GRBAS scores and acoustic and aerodynamic measures of voice. In order to illustrate the extent to which clinician and patient perceptions of voice disorders align, this study also examined the relationship between GRBAS ratings and VHI and GFI scores.

METHODS

Study Population

Data were sampled from the University of Wisconsin Madison (UW Madison) Voice and Swallow Clinics Outcomes Database. This prospective outcomes database is approved and monitored by the UW Madison School of Medicine and Public Health Institutional Review Board. Patients who present to the Otolaryngology Head and Neck Clinic with voice or swallow related problems are consented for the database. Information is prospectively collected each time patients are in clinic. This study included subjects over the age of 18 between the time of January 2008 and October 2019. At the time of this study, the database included information from approximately 6,364 patients. Only data from initial voice evaluations for patients presenting to the clinic with voice related complaints were included. In summary, subjects were included in the current study if they 1) presented to the clinic for a voice related complaint, 2) had GRBAS ratings and at least partial acoustic and aerodynamic data collected at their initial voice evaluation, and 3) were over the age of 18.

Demographic data collected from the outcomes database included age, otolaryngology diagnosis, and sex. Diagnoses were sorted into seven overarching diagnostic categories. These included; 1) benign vocal fold lesions, 2) nonorganic voice disorders (muscle tension dysphonia etc.), 3) vocal fold paralysis/paresis, 4) laryngeal cancer/papilloma, 5) neurologic voice disorders or underlying diseases (i.e., Spasmodic dysphonia, Parkinson's disease, etc.), 6) laryngeal edema or irritation, and 7) dysphonia associated with irritable larynx/laryngospasm. If patients presented with multiple disorders, they were categorized in the diagnostic group determined to be the primary etiology of dysphonia; this allowed for the statistical model to account for patient diagnosis.

GRBAS ratings collected from the database were performed by certified SLPs specializing in the treatment of voice disorders (or clinical fellows working under the direction of certified SLPs) at the time of initial patient evaluations. All SLPs working in this setting are trained on auditory-perceptual assessments using the GRBAS scale upon employment at UW Madison and clinicians meet periodically to ensure interrater reliability/rater consensus. In addition, clinical fellows undergo a two month period where they are supervised by a certified clinician during voice assessments. GRBAS ratings were performed in accordance with the protocol indicated by Hirano and colleagues.[16] Acoustic data gathered from the database included Noise to Harmonic ratio (NHR), jitter%, shimmer%, lowest frequency of vocal range, highest frequency of vocal range, maximum phonation time, and Dysphonia Severity Index (DSI) score. Aerodynamic measures collected from the database included phonation threshold pressure, aerodynamic resistance, subglottal pressure, and mean airflow. Patient reported quality of life measures obtained from the database consisted of the VHI and the GFI.

Statistical Analysis

Linear regression models were used to determine the effect of CAPE-V scores on acoustic/aerodynamic and patient-reported quality of life measures. ANOVA models with Tukey-Scheffe multiple comparisons were used to determine the correlation between GRBAS and other voice measures. The r^2 statistic was computed for corresponding linear models. All models controlled for variables of sex, age, and voice disorder diagnosis in order to clarify the relationship between GRBAS ratings and voice measures. Further analysis of these factors was considered outside the scope of the current study. Correlations were also assessed for sub-components of the GRBAS scale. All statistical analyses were conducted at the 0.05 significance level using the R software program (version 3.6.0).

RESULTS

Data from a total of 508 individuals were included in this study (mean age = 56.8, SD = 16.3). Of these 508 individuals, 310 were female and 198 were male. Table 1 includes the distribution of subject ages and diagnostic categories.

Correlations Between GRBAS Ratings and Acoustic Measures

Numerous acoustic measures were significantly correlated with GRBAS ratings. Table 2 contains p-values and r^2 values for all correlations. All acoustic measures were significantly correlated with overall grade of voice disorder, breathiness, asthenia, and strain. R^2 values ranged from low to medium range. The highest r^2 values for GRBAS ratings of overall voice quality were observed for NHR (r^2=.31, p<.001), shimmer% (r^2=.30, p<.001), highest frequency of vocal range (r^2=.29, p<.001), and lowest frequency of pitch range (r^2=.36, p<.001). Breathiness had the highest correlation with NHR (r^2=.28, p<.001), shimmer% (r^2=.32, p<.001), highest frequency of vocal range (r^2=.31, p<.001) and lowest frequency of pitch range (r^2=.37, p<.001), as was asthenia (NHR (r^2=.23, p<.001), shimmer% (r^2=.32, p<.001), highest frequency of vocal range (r^2=.37, p<.001) and lowest frequency of pitch range (r^2=.28, p<.001). This pattern also held true for strain NHR (r^2=.51, p<.001), shimmer% (r^2=.29, p<.001), highest frequency of vocal range (r^2=.28, p=.002) and lowest frequency of pitch range (r^2=.36, p<.001).

GRBAS ratings of roughness were only significantly correlated with jitter%, shimmer%, maximum phonation time and DSI. All r^2 values for these correlations were in low range.

Correlations Between GRBAS Ratings and Aerodynamic Measures

Several significant correlations were observed between GRBAS ratings and aerodynamic measures, however, r^2 values were in low range for all. Overall voice quality was significantly correlated with subglottal pressure (r^2=.16, p<.001) and mean airflow (r^2=.15, p<.001). Roughness was significantly correlated with these same measures. Breathiness was significantly correlated with all aerodynamic measures except aerodynamic resistance, with r^2 values remaining in low range. Asthenia was significantly correlated with airflow rate (r^2=.13, p<.001), and strain was significantly correlated with subglottal pressure, mean airflow and aerodynamic resistance. *P* values and r^2 values for all correlations between GRBAS ratings and aerodynamic measures are reported in Table 2.

Correlations Between GRBAS Ratings and Patient-Reported Quality of Life Measures

Table 2 presents *P* values and r^2 scores for all correlations between GRBAS ratings and patient reported quality of life measures. GRBAS ratings were significantly correlated with all VHI scores, however, r^2 values were in the low range for all correlations. The highest significant correlations were observed between overall grade of voice disorder and VHI total (r^2=.23, p<.001), physical (r^2=.22, p<.001) and functional scores (r^2=.25, p<.001). The functional subscale of the VHI was most correlated with roughness, breathiness, asthenia and strain although these r^2 values remained in low range. The GFI was significantly correlated with all GRBAS ratings with the exception of roughness. The highest significant r^2 value for GFI was observed for overall voice quality (r^2=.20, p<.001).

DISCUSSION

The relationship between auditory-perceptual ratings of voice quality – specifically those made using the GRBAS scale – and aerodynamic, acoustic and patient reported quality of life measures in adults with voice disorders is not fully understood. Inasmuch as auditory-perceptual ratings are often used to measure the effectiveness of voice therapy and quantify the severity of voice disorders, the relationship between GRBAS scores and acoustic and aerodynamic measures is important. Ideally, GRBAS ratings should be correlated with the acoustic and aerodynamic measures that reflect laryngeal function. The relationship between GRBAS ratings and patient-reported quality of life measures is also key as patient-perceived voice outcomes drive treatment adherence. This study examined the relationship between GRBAS ratings and objective measures, as well as the VHI and GFI, in 508 adults with voice disorders. GRBAS scores were correlated with multiple acoustic, aerodynamic and patient reported quality of life measures, however, r^2 values were in low to medium range for these correlations.

Correlations Between GRBAS Ratings and Acoustic Measures

Firstly, it should be noted that GRBAS ratings were significantly correlated with most of the acoustic measures examined in this study. This would indicate that the ratings made by clinicians reflected objective acoustic analysis of patient voices. This correlation is reassuring as the relationship between auditory-perceptual and objective voice measures has been described as tenuous.[9,10] The fact that all ratings were performed by clinicians specifically trained in the assessment and treatment of voice disorders may be partially responsible for these results as professional specialty can influence auditory-perceptual ratings.[13] It is possible that in a setting where clinicians are less specialized in the assessment and treatment of voice, the relationship between GRBAS scores and other voice measures might be weaker. It is also interesting to note that despite using expert raters, r^2 values remained in low to medium range. This would indicate that no single voice measure explained a high amount of the variation in GRBAS score and would support the current clinical practice of using multiple types of voice measures to assess vocal pathology.[1]

For acoustics, GRBAS ratings were most correlated with measures of perturbation and vocal frequency range. Several of these measures warrant additional discussion. NHR was significantly correlated with GRBAS ratings of overall quality, breathiness, asthenia and strain.

This is not surprising as past study has demonstrated NHR to be strong predictor of auditory-perceptual ratings of breathiness and roughness.[23] In fact, NHR has been found to account for anywhere from 30 – 50% of the variance in ratings of breathiness.[23,24] In addition, multiple studies have observed that improvements in NHR align with improvements in the auditory-perceptual rating categories observed in this study.[25,26] It was unexpected, however, that NHR was not significantly correlated with roughness, as past studies have observed a significant correlation between this auditory-perceptual quality and this measure.[9,23] This difference in findings may be due in part to smaller sample sizes studied in past works[9] or methodological differences.[23] Clinically, we have also observed that some facilities may consider vocal fry as roughness, while others may not. These differences could complicate ratings and contribute to inconsistencies in research findings.

Shimmer% and Jitter% were also significantly correlated with all GRBAS ratings. This finding is supported by previous studies that have found perturbation measures to partially predict ratings of voice quality.[23,27] In addition, improvements in these measures have been observed to be associated with improvements in auditory-perceptual voice assessments.[25] It should be noted that although significant correlations between these measures were observed, r^2 values were in low range – indicating that jitter% and shimmer% did not account for a large portion of the variation in GRBAS scores. This supports past studies suggesting that perturbation measures are not without their limitations. For instance, these measures have been demonstrated to have limited capacity to assess severely dysphonic voices, which are often less periodic in nature.[28,29]

The DSI was included to determine if this composite measure, designed to be a an objective correlate of voice quality,[30] would work differently than simple perturbation measures. The strongest correlation found indicated that DSI accounted for 29% of the variation in overall voice quality. This finding is supported by past studies which have shown that the DSI is correlated with auditory-perceptual ratings of overall grade.[31] It is interesting, however, that the

DSI did not account for more of the variation in GRBAS scores than the basic measures of perturbation such as Jitter% and shimmer%. In fact, r^2 values were higher overall for shimmer%. This may be because the DSI is effective at separating normal and dysphonic voices, but may be less sensitive to smaller changes in vocal quality between extremes. This could explain why all correlations were significant while r^2 values were low. Regardless, it is interesting to note that despite other potential benefits to the DSI,[32–34] this measure did not better predict variability in GRBAS scores than basic perturbation measures.

To our knowledge, the relationship between vocal frequency range and GRBAS ratings has only been indirectly examined, as vocal range is included in the DSI calculation. The current study found that both lowest and highest frequency of vocal range were significantly correlated with all GRBAS ratings. These results suggest that vocal range may be associated with vocal quality, presumably because laryngeal pathology often impacts vocal range and quality to a similar extent. In fact, there is emerging evidence that upper frequency range may be representative of the overall health/fitness of the voice and swallow mechanism as these functions share partially common biomechanics.[35–37] This may be why commonly prescribed voice treatments such as the vocal function exercises utilize pitch glides to promote improved vocal function/quality.[38] Further study is needed, however, to understand the relationship between frequency range and GRBAS ratings.

Correlations Between GRBAS Ratings and Aerodynamic Measures

GRBAS ratings of overall voice quality, roughness, breathiness and strain were significantly correlated with subglottal pressure and mean airflow rate. R^2 values were in low range. Theoretically, it makes sense that these voice measures would be correlated with vocal quality as laryngeal pathologies known to affect GRBAS ratings also alter respiratory physiology during speech.[39,40] In addition, aerodynamic measures have even been shown to reflect laryngeal pathology in general,[41] as well as vocal effort.[42]

In addition to subglottal pressure and mean airflow, GRBAS ratings of breathiness were also correlated with phonation threshold pressure. This may be due to the fact that increased vocal fold thickness and stiffness affect phonation threshold pressure and can lead to increased breathiness.[43,44] It is perhaps surprising that other GRBAS ratings outside of breathiness were not significantly correlated with phonation threshold pressure, as these changes in physiology could lead to changes in the other auditory-perceptual parameters as well. Aerodynamic resistance was only significantly correlated with GRBAS ratings of strain. Again, this makes sense physiologically as aerodynamic resistance reflects laryngeal constriction which is thought to increase with vocal effort or strain.[4]

Although there were multiple significant correlations with aerodynamic measures, it should be remembered that all r^2 values were in low range and therefore more work is needed to understand the relationship between GBRAS ratings and aerodynamic voice measures. It should also be remembered that this study controlled for patient diagnosis, however, these findings suggests that aerodynamic measures alone may not adequately assess voice quality. This is perhaps not surprising given that aerodynamic measures primarily measure physiology.

Correlations between GRBAS ratings and Patient-Reported Quality of Life Measures

VHI total and sub-scores were significantly correlated with all GRBAS ratings. The highest correlations were observed between GRBAS scores of overall voice quality and VHI total (r^2=.22), VHI physical (r^2=.23) and VHI functional (r^2=.25). This would indicate that the relationship between the VHI and overall voice quality is stronger than any specific auditory-perceptual parameters. The VHI parameter with the highest correlations across auditory-perceptual parameters was the functional sub-score. It makes sense that questions directly assessing vocal function, rather than emotional or physical side effects, were best correlated with changes in voice quality. Again, all correlations had r^2 values in low range indicating that VHI scores did not explain much of the variation in GRBAS ratings. This may be because the

VHI is primarily designed to detect changes in patient voice-related experience,[20,45] which is influenced by vocal quality but also affected by other factors.

The GFI was significantly correlated with all GRBAS ratings except roughness, however, r^2 values remained in the low range. R^2 values were lower than those observed for the VHI, which would indicate that although this scale predicted some variability in voice quality, the VHI predicted slightly more. This may be because the VHI includes more questions which may more thoroughly assess vocal function. That said, considering how time-efficient the GFI is with only four questions, clinicians may find it a useful choice for certain situations, particularly as r^2 values were in a similar range when comparing the VHI and GFI and ratings of overall voice quality.

CONCLUSION

GRBAS ratings were correlated with several acoustic and aerodynamic measures. In addition, VHI and GFI scores were also correlated with GRBAS ratings. R^2 values were in low to medium range across all correlations. Although there was a relationship between GRBAS ratings and other voice measures, this relationship was weak. These findings support the need for multiple voice measures when performing voice evaluations as no single voice measure explained high amounts of variation in voice quality as measured by the GRBAS scale.

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Table Legends

Table 1. Population Demographics

Table 2. Correlations Between GRBAS Ratings and Voice Measures

Population Demographics

	Number of Participants	Mean Age (SD)
Overall	508	56.8 (16.3)
Female	310	59.7 (15.8)
Male	198	54.9 (16.3)
Diagnostic groups		
Benign vocal fold lesions	100	49.3 (16.1)
Non-organic voice disorders	114	56.6 (16.3)
Laryngeal paralysis/paresis	116	60.9 (15.2)
Laryngeal cancer/papilloma	10	57.4 (13.6)
Neurologic voice disorders	51	65.2 (14.2)
Laryngeal edema/irritation	88	55.1 (16.6)
Irritable larynx/laryngospasm	29	57.9 (12.0)

Table 2

Correlations Between GRBAS Ratings and Voice Measures

VOICE MEASURES	***OVERALL GRADE***		***ROUGHNESS***		***BREATHINESS***		***ASTHENIA***		***STRAIN***	
Acoustics	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**
Jitter %	.24	<.001*	.12	<.001*	.17	<.001*	.16	<.001*	.13	<.001*
Shimmer %	.30	<.001*	.28	<.001*	.32	<.001*	.32	<.001*	.29	<.001*
NHR	.31	<.001*	.13	.110	.28	<.001*	.23	<.001*	.51	<.001*
Low Freq. Range	.36	<.001*	.34	.152	.37	<.001*	.37	<.001*	.36	<.001*
Upper Freq. Range	.29	<.001*	.25	.047	.31	<.001*	.28	<.001*	.28	.002*
MPT	.17	<.001*	.14	.001*	.18	<.001*	.15	<.001*	.14	.004*
DSI	.29	<.001*	.14	<.001*	.25	<.001*	.20	<.001*	.19	<.001*
Aerodynamics	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**
PTP	.02	.796	.02	.573	.04	.006*	.02	.906	.02	.705
Subglottal Pressure	.16	<.001*	.12	.001*	.11	.002*	.10	.417	.16	<.001*
Mean Airflow Rate	.15	<.001*	.11	.032*	.19	<.001*	.13	<.001*	.12	.002*
Aero. Resistance	.06	.837	.07	.495	.07	.255	.07	.379	.08	.014*
Patient Reported Quality of Life	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**	**r^2**	***p* value**
GFI	.20	<.001*	.12	.046	.16	<.001*	.13	.001*	.19	<.001*
VHI Total	.23	<.001*	.11	<.001*	.17	<.001*	.16	<.001*	.20	<.001*
VHI -Functional	.25	<.001*	.13	<.001*	.22	<.001*	.21	<.001*	.22	<.001*
VHI -Emotional	.14	<.001*	.08	<.001*	.10	<.001*	.10	<.001*	.16	<.001*
VHI -Physical	.22	<.001*	.11	<.001*	.16	<.001*	.13	<.001*	.17	<.001*

*Indicates significant association

NHR (noise to harmonics ratio), MPT (maximum phonation time), PTP (phonation threshold pressure), GFI (Glottal Function Index), VHI (Voice Handicap Index)