A Comparison of Trained and Untrained Vocalists on the Dysphonia Severity Index

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Summary: The purposes of this study were (1) to compare trained and untrained singers on the Dysphonia Severity Index (DSI) and its component measures, and (2) to contribute to normative DSI data for trained singers. This study included 36 untrained participants (15 males and 21 females) and 30 participants (15 males and 15 females) with singing experience between the ages of 18 and 30 years. Measures of maximum phonation time (MPT), highest phonational frequency, lowest intensity, and jitter were obtained for each subject and incorporated into the previously published multivariate DSI formula. Results indicated that vocally trained subjects have significantly higher DSI scores than untrained subjects (mean DSI: 6.48 vs 4.00, respectively), with significant differences observed between trained and untrained groups for three of the four components of the DSI (F₀ high; I low; jitter). The findings of this study are consistent with previous reports that indicate significant increases in the DSI with vocal training, and with various studies that have observed increased vocal capability in trained singers versus their untrained counterparts. The results of this study indicate that alternative normative expectations for the DSI may need to be taken into account when using the DSI with patients who have participated in directed vocal training, such as choral participation and voice/singing lessons.

Key Words: Dysphonia Severity Index–Singers–Maximum phonation time–Jitter–Phonational frequency range.

INTRODUCTION

The perceptual evaluation of voice is considered to be an essential aspect of the conventional voice diagnostic that has relevance to most voice-disordered patients and provides a global measure of vocal performance readily available to all clinicians. 1–3 Although perceptual evaluation of voice has obvious importance, there are several limitations associated with this method of assessment that clearly influence its clinical utility. These limitations include problems with scale validity and reliability, particularly for midscale (ie, mild to moderate) pathological voices; lack of credibility for medical-legal purposes; poorly defined and/or shifting definitions of severity; and the intrusive effects of voice and speech characteristics other than the quality dimension that is meant to be judged. 1–13 Many of these limitations stem from the attempt to describe the voice via a temporary auditory impression of the acoustic signal. As a response, voice clinicians and researchers have added to the perceptual assessment of voice quality with other methods that provide a permanent record of the vocal behavior and allow for a more objective analysis of the patient’s voice quality.

Acoustic methods of voice analysis have been primary tools of both the clinician and the researcher for many years. These methods have become widely used in both research and clinical situations since the advent of relatively low-cost personal computers and analog-to-digital acquisition hardware in the early 1990s, and have the benefits of being noninvasive; readily available at relatively low cost compared with other methods of voice analysis; applicable to treatment and diagnosis; and are supported by a substantial body of literature. 4 Multiparameter acoustic models, which may be used to characterize voice function and quantify the severity of dysphonia, have been presented by Michaelis et al, 5 Callan et al, 6 Fröhlich et al, 7 and Awan and Roy. 8–10

An alternative method for encompassing the multidimensional nature of the normal versus disordered voice is the Dysphonia Severity Index (DSI). The DSI was developed by Wuyts et al 11 with the purpose of developing an index that would both objectively and quantitatively correlate with perceived voice quality. The DSI makes use of a combination of several voice measures that may be obtained from voice-assessment procedures, such as the voice range profile and basic aerodynamic and acoustic analyses: the highest phonational frequency (F₀ high in Hz), lowest intensity (I low in dB), maximum phonation time (MPT in seconds), and jitter (%). Because voice has been described as a multiparameter behavior, it appears reasonable that a multiparameter model, such as that presented in the DSI, may be useful in describing vocal function. 12 The components of the DSI form a specific combination of acoustic voice measures that may aid in characterizing various types of vocal dysfunction. Wuyts et al 11 stated that, when extra mass is evenly distributed along the true vocal fold(s), the higher vibratory rates become dampened. The result is a decrease in the upper reaches of the phonational frequency range. Structural changes to the true vocal folds, such as distributed or organized mass lesions, may increase glottal resistance such that greater subglottal pressures will be necessary to initiate and maintain vocal fold vibration. Consequently, the lowest phonational intensity will often be increased. In addition to changes in vocal intensity, vocal fold pathology (eg, unilateral or bilateral organized lesions or distributed tissue change; organic pathology affecting the ability to effectively tense or approximate the folds during phonation) often results in disturbances in the periodicity of phonation. These disturbances may be described in terms of jitter, a measure of short-term instability that quantifies cycle-to-cycle variations in frequency and has been used to assess the degree of perturbation in the voice signal. Finally, MPT has
been regarded as a general measure of phonatory ability\textsuperscript{13} that reflects the function of several mechanisms necessary for voice production, such as respiratory capacity and control, subglottic pressure, airflow resistance, and closure of the vocal folds. The DSI was initially described and validated in a study by Wuyts et al.\textsuperscript{11} in which the authors obtained various acoustic and commonly used aerodynamic measures from 387 subjects (68 normal controls vs 319 voice-disordered subjects). In addition, each patient’s voice was perceptually rated using the grade, roughness, breathiness, asthenia, strain (GRBAS) scale.\textsuperscript{12} The DSI was obtained via multiple regression analyses and consists of four weighted variables in the equation: $DSI = 0.13 \times MPT (\text{seconds}) + 0.0053 \times F\text{O}_0 \text{ high (Hz)} - 0.26 \times I \text{ low (dB)} - 1.18 \times \text{jitter (\%)} + 12.4$. Results of the study indicated an inverse relationship between the DSI and the grade (overall severity) of dysphonia, as well as between the DSI and the Voice Handicap Index (VHI). The DSI was transformed such that a $DSI = +5$ corresponded to $G_0$ (normal voice), and a $DSI = -5$ corresponded to $G_3$ (severe dysphonia). It was noted by these authors that the DSI is not necessarily restricted to the $+5$ to $-5$ range. A $DSI$ of $+1.6$ was determined to be the cutoff for perceptually normal voices.

Several studies have used the DSI to objectively describe normal versus disordered voice characteristics and change in voice over time. Timmermans et al.\textsuperscript{14} evaluated voice quality change in 68 students (49 received voice training; 19 served as an untrained control group). The vocally trained group was provided with instruction regarding relaxation, posture, breathing pattern, and active articulation. Results showed a significant increase in the DSI for the trained group (from 2.3 to 4.5) versus no significant change in the untrained group. In a second study, Timmermans et al.\textsuperscript{15} used the DSI as a method of evaluating the effectiveness of a voice-training program for 23 professional voice users. The DSI scores were again observed to significantly increase from the time of training onset (mean $DSI = 2.0$) to 9 months post-training onset (mean $DSI = 3.7$) and to 18 months post-onset (mean $DSI = 4.6$), with the most prominent voice-characteristic change being increases in $F\text{O}_0$ high. Hakkesteegt et al.\textsuperscript{16} investigated the possible influence of age and gender on the DSI (69 females; 49 males between 20 and 79 years of age). Although significant differences between males and females were observed for $F\text{O}_0$ high and MPT, the mean DSI between the genders was not significantly different (mean DSI: females $= 4.3$; males $= 3.8$). The DSI was observed to decrease significantly with age in both genders, primarily because of reductions in $F\text{O}_0$ high and low intensity. These authors inferred that the DSI of a particular voice patient should be compared with appropriate normative data from comparable age and gender subjects. Woisard et al.\textsuperscript{17} examined the possible correlation between a French version of the VHI and quantitative methods of describing voice, including the DSI. In contrast to Wuyts et al.\textsuperscript{11} no significant correlation between the VHI and the DSI was observed. Woisard et al.\textsuperscript{17} indicated that the DSI should be seen as a source of clinical information independent of the VHI. Hakkesteegt et al.\textsuperscript{18} reported on the interobserver and test-retest variability of the DSI. Thirty normal subjects were measured by two speech pathologists on three different days (approximate interval of 1 week between measurements). The interobserver variability in measurement was observed to be low with very little influence on DSI variability. In addition, any differences in DSI measurement between the observers were reported as nonsignificant. These authors determined that intrasubject DSI changes needed to exceed 2.49 to be significant. Hakkesteegt et al.\textsuperscript{19} investigated the possible relationship between the GRBAS scale and the DSI. The subjects included 294 voice-disordered patients and 118 normal controls. Significantly lower DSI and higher grade (overall severity) scores were observed in disordered versus control groups. In addition, a DSI score of 3.0 was observed to discriminate between control and disordered groups with sensitivity $= 0.72$ and specificity $= 0.75$. It was observed that DSI scores may be reduced even for patients with overall grade/severity scores $= 0$, indicating that the voice complaints of some patients may not be solely quality based. Most recently, Hakkesteegt et al.\textsuperscript{20} examined the possible relationship between the DSI and the VHI. Pre- and postintervention measures were obtained from 171 voice-disordered patients. The subjects were divided into voice therapy, surgical intervention, and no intervention groups. Consistent with Woisard et al.,\textsuperscript{17} results indicated that the DSI and VHI measure different aspects of a voice disorder, with the VHI being a measure of patient perception and the DSI a measure of vocal performance/capability. Although both methods were able to show differences between pre- and postintervention groups, these authors indicated that DSI and VHI are not necessarily related.

The DSI has been reported to be a valuable clinical tool for the quantitative description of normal versus disordered voice. However, as indicated by Hakkesteegt et al.,\textsuperscript{16} extended normative data that will provide focused comparisons for subgroups of the normal population are necessary for appropriate clinical interpretations. A subgroup of the normal population that may be seen for voice complaints is that of the trained singer. Voice training has been said to influence the morphology and the control over the voice source.\textsuperscript{21} Although inconclusive, several research studies have reported that trained singers may have increased respiratory capacities and different respiratory postures as compared with untrained subjects;\textsuperscript{22–25} may have greater $F\text{O}_0$ ranges than the normal untrained population;\textsuperscript{26–28} and greater dynamic range capability.\textsuperscript{27,29,30} In addition, Sulter et al.\textsuperscript{31} speculated that trained singers may have developed improved breath control during voicing, resulting in the ability to produce vocal fold oscillation at lower subglottal pressures. Whether these reported differences between trained and untrained singers are specifically the result of training itself; the regular participation in experiences such as choral singing; or to inherent physiological differences in those who choose to regularly participate in directed singing, is unclear. However, with these possible differences in mind, it would appear that DSI values for trained singers may be substantially different from those reported for untrained participants. Because of possible increased vocal capabilities, it may be that a trained singer who is experiencing some aspect of vocal dysfunction could still obtain a DSI score within the expected values reported by Wuyts et al.\textsuperscript{11} The availability of data from trained singers...
will make normative expectations for this index more applicable to a greater base of potential patients, and allow for more appropriate clinical decisions regarding this population. Therefore, the purposes of this study were (1) to compare trained versus untrained singers on the DSI and its component measures, and (2) to contribute to normative DSI data for trained singers.

**METHODOLOGY**

**Subjects**

The methodology used in this study adhered to the basic ethical considerations for the protection of human participants in research and was approved by the Bloomsburg University Institutional Review Board. This study included 66 subjects (36 untrained participants [15 males and 21 females]; 30 participants [15 males and 15 females] with singing experience) between the ages of 18 and 30 years. An untrained participant had no formal voice/singing lessons and no directed singing experience (choral experience, etc) beyond middle school age. A trained participant had participated in directed singing experience since middle school age. Directed singing experience included private voice lessons and/or regular participation in a choir or musical theater under the guidance of a trained musical director. The criteria used to gauge singing experience in this study were similar to those used by Sulter and Peters and McCrae and Morris. The trained male and female subjects reported receiving an average of 3.50 and 4.89 years of private voice lessons, respectively (Table 1). At the time of testing, subjects reported receiving an average of 3.50 and 4.89 years of private voice lessons, respectively (Table 1). At the time of testing, subjects reported receiving an average of 3.50 and 4.89 years of private voice lessons, respectively (Table 1).

**Procedures**

Each subject was asked to complete the following tasks:

1. Highest phonational frequency \(F_0\) high): Each subject was asked to go up a scale (using the vowel /q/) until they reached their highest pitch level without losing control of the voice (ie, no pitch or phonation breaks). The highest pitch level was digitally recorded at 44.1 kHz, 16 bits of resolution using Sound Forge v. 4.0 and later analyzed using the TF32 speech/voice analysis program for the highest frequency level (in Hz). Three trials were elicited.

2. Lowest intensity level \(I_{low}\): Each subject was asked to sustain the vowel /a/ at a comfortable pitch as quietly as possible. Three trials were elicited. Each production was analyzed for the intensity level (in dB) using Aerophone II. Calibration of all key components of the Aerophone II system was conducted according to the manufacturer’s instructions. According to the manual, the microphone included in the Aerophone II system (AKG type CK77P-3L electret condenser microphone, AKG Acoustics GmbH, Vienna, Austria) is precalibrated by means of a Bruel and Kjaer Integrating Precision Sound Level Meter (Type 2230, Brüel & Kjaer Sound and Vibration Measurement A/S, Naerum, Denmark). A calibration factor is provided with the system and entered when installing the system. The mouth-to-microphone distance was 15 cm. To convert this to the commonly used 30-cm mouth-to-microphone distance, 6 dB may be subtracted from the 15-cm mouth-to-microphone distance intensity level. Sound intensity is expected to decrease by 6 dB when the distance from the source is doubled.

3. Jitter: To obtain a measure of jitter, the subject was instructed to chant “1, 2, 3, 4” at a comfortable pitch and loudness and then sustain the vowel /q/ for 2–3 seconds at that similar pitch level. This elicitation method was used to obtain a vowel sample that closely approximates the subjects’ habitual speaking pitch. Three trials were

| TABLE 1. Means of Subjects’ Age and Height, as Well as Mean Number of Years of Participation in Directed Singing Experiences for the Trained Subjects |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Demographics    | Trained Males   | Trained Females | Untrained Males | Untrained Females |
| Age (y)         | 20.40 (1.76)    | 21.46 (2.92)    | 21.66 (2.47)    | 22.57 (4.03)    |
| Height (cm)     | 175.43 (5.03)   | 164.25 (9.44)   | 179.15 (6.91)   | 164.13 (5.53)   |
| Voice lessons (y)| 3.50* (1.84)    | 4.89* (4.01)    | N/A             | N/A             |
| Participation in choir, musical theater (y) | 7.93 (3.98) | 8.00 (2.93) | N/A | N/A |

SDs are provided in parentheses.
Abbreviation: N/A, not applicable; y, years.
* Average of 2.0 h/wk.
1 Average of 3.5 h/wk.
Dysphonia severity index formula
As previously mentioned, the DSI formula is derived from a weighted combination of the following vocal parameters: highest frequency (Hz), lowest intensity (dB), MPT (seconds), and jitter (%). For each subject, the DSI was calculated using the maximum performances for $F_0$ high and MPT, the lowest intensity, and the lowest jitter.$^{18}$ The results were entered into the following formula:

$$DSI = 0.13 \times MPT \text{ (seconds)} + 0.0053 \times F_0 \text{ high (Hz)} - 0.26 \times I \text{ low (dB)} - 1.18 \times \text{jitter (％)} + 12.4$$

RESULTS
All statistical procedures were conducted using SPSS v. 15.0 for Windows.$^{17}$ Where necessary, significant interaction effects were analyzed using Tukey Honestly Significant Different (HSD) means comparison tests.

Analysis of maximum phonation time (Seconds)
A two-way analysis of variance (ANOVA) was conducted to assess the possible differences in MPT (two levels of group—trained vs untrained subjects; two levels of gender). Results indicated no significant difference between the trained versus untrained groups ($F(1, 62) = 0.76; P = 0.38$). Although there was a tendency for males to produce longer MPTs than females (22.78 seconds [standard deviation (SD) = 6.94] vs 19.71 seconds [SD = 6.62], respectively), no significant gender effect ($F(1, 62) = 3.56; P = .06$) and no significant interaction effects ($F(1, 62) = 0.02; P = .90$) were observed. Means and SDs for the MPTs of the trained versus untrained subjects, as well as for male and female subgroups are provided in Tables 2 and 3.

Analysis of maximum frequency (Hz)
A two-way ANOVA was conducted to assess the possible differences in maximum phonational frequency ($F_0$ high). Results indicated significant main effects of group ($F(1, 62) = 26.71; P < 0.0001$), and gender ($F(1, 62) = 24.31; P < 0.0001$). Results indicated that the mean $F_0$ high for the trained subjects was significantly greater than that observed for untrained subjects (805.01 vs 591.86 Hz, respectively). As expected, female subjects produced significantly greater mean $F_0$ high than male subjects (776.01 Hz [SD = 226.69] vs 584.03 Hz [SD = 190.15], respectively). No significant interaction of group and gender was observed ($F(1, 62) = 1.85; P = 0.18$). Means and SDs for $F_0$ high are provided in Tables 2 and 3.

Analysis of low intensity (dB)
A two-way ANOVA was conducted to assess the possible differences in low intensity phonation ($I$ low). Results indicated a significant main effect of group ($F(1, 62) = 26.02; P < 0.0001$), with trained subjects observed to produce significantly lower-intensity productions than untrained subjects (47.97 vs 53.34 dB, respectively—see Table 2). No significant effect of gender was observed ($F(1, 62) = 0.01; P = 0.98$). However, a significant interaction of group and gender was observed ($F(1, 62) = 18.94; P < 0.0001$). Post hoc investigation of the significant interaction effect using Tukey HSD means comparison tests indicated that untrained females produced significantly lower intensity phonations compared with untrained males. In contrast, trained males produced significantly lower-intensity phonations than trained females. In addition, trained males produced significantly lower-intensity phonations than untrained males. No significant difference was observed between untrained and trained females (Table 3).

Analysis of jitter (%)
A two-way ANOVA was conducted to assess the possible differences in jitter (%). Results indicated a significant main effect of group ($F(1, 62) = 4.81; P = 0.03$), with results indicating that trained subjects had significantly lower jitter than untrained subjects (0.31% vs 0.41%, respectively—see Table 2). No significant effects of gender ($F(1, 62) = 0.25; P = 0.62$) or group and gender interaction ($F(1, 62) = 0.52; P = 0.47$) were observed (Table 3).

Analysis of the dysphonia severity index
A two-way ANOVA was conducted to assess the possible differences in the DSI. Results indicated a significant main effect of group ($F(1, 62) = 26.15; P < 0.0001$), with the trained subjects observed to have significantly higher DSI scores than untrained subjects (6.48 vs 4.00, respectively—see Table 2). No significant gender effect was observed ($F(1, 62) = 1.85; P = 0.18$). Although a tendency was observed for untrained females to have greater DSI scores than untrained males, no significant differences in the DSI. Results indicated a significant main effect of group ($F(1, 62) = 26.15; P < 0.0001$), with the trained subjects observed to have significantly higher DSI scores than untrained subjects (6.48 vs 4.00, respectively—see Table 2). No significant gender effect was observed ($F(1, 62) = 1.85; P = 0.18$). Although a tendency was observed for untrained females to have greater DSI scores than untrained males, no significant

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trained Vocalists</th>
<th>Untrained Vocalists</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPT (s)</td>
<td>20.43 (5.30)</td>
<td>21.67 (8.01)</td>
</tr>
<tr>
<td>$F_0$ High (Hz)</td>
<td>805.01 (227.01)</td>
<td>591.86 (185.64)</td>
</tr>
<tr>
<td>$I$ low (dB)</td>
<td>47.97 (5.99)</td>
<td>53.34 (4.26)</td>
</tr>
<tr>
<td>Jitter (%)</td>
<td>0.31 (0.11)</td>
<td>0.41 (0.20)</td>
</tr>
<tr>
<td>DSI</td>
<td>6.48 (2.19)</td>
<td>4.00 (2.04)</td>
</tr>
</tbody>
</table>

SDs are provided in parentheses.
Western singing training generally includes exercises and/or warm-ups that may involve pitch matching, pitch glides, and pitch (musical) scales, it is of no surprise that trained subjects may be able to produce greater frequency ranges and maximum frequencies than untrained subjects. The observation of significantly higher maximum frequency ($F_0$ high) production in females versus males is expected, and consistent with previous findings by Wuyts et al.\textsuperscript{11} and Hakkesteegt et al.\textsuperscript{16} Even though females characteristically produce higher maximum frequency productions as compared with males, this difference is generally offset by greater MPTs in males than females. The result is that the DSI scores for the genders tend not to differ significantly.\textsuperscript{11}

The trained singers were observed to have significantly lower minimum intensity ($I_{low}$) productions than untrained subjects. This finding is consistent with literature that has indicated increased phonatory control and a lowering of the minimum intensity capability for subjects who have undergone focused vocal training.\textsuperscript{21,27,39} Vocal-training exercises that promote increased vocal fold thickness and increase breath support and control tend to be conducive to lower minimum intensity productions.\textsuperscript{21} In addition, Western singing training often includes various respiratory exercises/warm-ups that focus on the proper use and strengthening of the abdominal muscles and diaphragm,\textsuperscript{38} as well as a focus on optimal posture and respiratory support during both singing and speech tasks, which may enable those with vocal training to produce greater ranges of vocal intensities.

The results of this study showed that trained subjects had significantly lower jitter than untrained subjects. Although a significant difference in jitter between the trained and untrained groups was observed, both groups produced jitter values well within normative expectations (generally expected to be substantially less than 1%.\textsuperscript{4,40}) In addition, the normal jitter results for both groups are consistent with the perception of normal voice quality of all the subjects included in this study. It is known that subjects can have normal voice quality and measures of jitter, and yet differ in terms of the DSI. This result clearly emphasizes that the DSI should be interpreted as a measure of vocal function/performance, and is not necessarily a correlate of perceived or measured vocal quality.\textsuperscript{19}

The DSI has the potential to be a useful diagnostic and clinical tool in regard to a variety of patients who may be experiencing voice difficulties. Although the DSI results of untrained

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### TABLE 3.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trained Males (n = 15)</th>
<th>Trained Females (n = 15)</th>
<th>Untrained Males (n = 15)</th>
<th>Untrained Females (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPT (s)</td>
<td>22.14 (5.53)</td>
<td>18.73 (4.61)</td>
<td>23.42 (8.26)</td>
<td>20.42 (7.78)</td>
</tr>
<tr>
<td>$F_0$ high (Hz)</td>
<td>667.31 (197.89)</td>
<td>942.71 (164.16)</td>
<td>500.75 (144.47)</td>
<td>656.94 (187.15)</td>
</tr>
<tr>
<td>$I_{low}$ (dB)</td>
<td>45.49 (6.63)</td>
<td>50.45 (4.17)</td>
<td>56.19 (4.24)</td>
<td>51.30 (2.94)</td>
</tr>
<tr>
<td>Jitter (%)</td>
<td>0.32 (0.12)</td>
<td>0.31 (0.10)</td>
<td>0.38 (0.13)</td>
<td>0.43 (0.24)</td>
</tr>
<tr>
<td>DSI</td>
<td>6.61 (2.52)</td>
<td>6.35 (1.90)</td>
<td>3.04 (1.98)</td>
<td>4.69 (1.83)</td>
</tr>
</tbody>
</table>

SDs are provided in parentheses.

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### DISCUSSION

The results of this study indicate that vocally trained subjects have significantly higher DSI scores than untrained subjects. Significant differences were observed between trained and untrained groups for three of the four components of the DSI ($F_0$ high, $I_{low}$, jitter). The findings of this study are consistent with the reports of Timmermans et al.\textsuperscript{14,15} which indicated significant increases in the DSI with vocal training, and with various studies which have observed increased vocal capability in trained singers versus their untrained counterparts.\textsuperscript{23–30} Although it is unclear from the results of this study as to whether the significantly increased DSI scores for the trained subjects are specifically the result of training, consistent participation in singing/choral activities, innately increased vocal capabilities in these subjects, or some combination of these factors, the difference in the mean DSI scores (6.48 for trained subjects vs 4.00 for untrained) is substantial and primarily related to increased frequency and dynamic range.

In light of previous reports of increased vital capacity in trained singers, it was somewhat surprising that there was no significant difference between the trained singers and the untrained subjects on measures of MPT. However, this finding has some similarity to the observations of Sulter and Meijer,\textsuperscript{21} in which MPT was observed to decrease post-vocal training. These authors attributed a decrease in phonation time to a decrease in glottal resistance and a more relaxed vocal fold posture. It is also speculated that the trained subjects may not have performed to their maximum potential on this particular task, despite prompting during the elicitation of all DSI component measures, because they were hesitant to “stress” their vocal mechanism. In addition, it may have seemed unnatural for the trained subjects to continue sustained phonation even as breath support became substantially reduced.

Several studies have indicated that there may be increased frequency ranges and high frequency production in trained singers.\textsuperscript{26–28} In addition, in studies by Mendes et al.\textsuperscript{38} and LeBorgne and Weinrich,\textsuperscript{39} significant increases in frequency range when compared before and after vocal training are reported. As Western singing training generally includes exercises and/or
vocalists reported in this study are consistent with the data of untrained vocalists reported in previous literature, the results of this study indicate that alternative normative expectations for the DSI may need to be taken into account when using the DSI with patients who have participated in directed vocal training or singing experience. The results of this study clearly indicate that DSI scores for subjects with vocal/singing training may substantially exceed previously reported mean DSI values for normal untrained subjects. Although the current literature includes results showing changes in DSI for those who undergo vocal training, specific norms for subjects who have continued their participation in vocal training or singing tasks over multiple years of experience are lacking. The results of this study provide preliminary DSI expectations for more experienced vocalists. Future studies should extend these preliminary norms to include larger samples and alternative forms of vocal experience beyond the choral/musical theater background for the subjects in this study.

Acknowledgment

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