Evaluating Voice Characteristics of First-Year Acting Students in Israel: Factor Analysis

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Summary: Hypothesis. Acting students require diverse, high-quality, and high-intensity vocal performance from early stages of their training. Demanding vocal activities, before developing the appropriate vocal skills, put them in high risk for developing vocal problems.

Study Design. A retrospective analysis of voice characteristics of first-year acting students using several voice evaluation tools.

Methods. A total of 79 first-year acting students (55 women and 24 men) were assigned into two study groups: laryngeal findings (LFs) and no laryngeal findings, based on stroboscopic findings. Their voice characteristics were evaluated using acoustic analysis, aerodynamic examination, perceptual scales, and self-report questionnaires. Results obtained from each set of measures were examined using a factor analysis approach.

Results. Significant differences between the two groups were found for a single fundamental frequency (F_0)-Regularity factor; a single Grade, Roughness, Breathiness, Asthenia, Strain perceptual factor; and the three self-evaluation factors. Gender differences were found for two acoustic analysis factors, which were based on F_0 and its derivatives, namely an aerodynamic factor that represents expiratory volume measurements and a single self-evaluation factor that represents the tendency to seek therapy.

Conclusions. Approximately 50% of the first-year acting students had LFs. These students differed from their peers in the control group in a single acoustic analysis factor, as well as perceptual and self-report factors. No group differences, however, were found for the aerodynamic factors. Early laryngeal examination and voice evaluation of future professional voice users could provide a valuable individual baseline, to which later examinations could be compared, and assist in providing personally tailored treatment.

Key Words: Acting students–Acoustic analysis–Aerodynamic–Perceptual evaluation–Self-evaluation–Factor analysis.

INTRODUCTION

Voice disorders can result from anatomic, physiological, or functional abnormal changes in the voice mechanism that interfere with the individual's ability to meet his/her habitual or professional demands of vocal use.[1] Therefore, vocal pathologies can be attributed to: (1) changes in laryngeal structure, physiological, or neurologic function; (2) changes in respiratory or resonance function; or (3) functional, behavioral, or psychological conditions that lead to vocal malfunction or inefficiency.[2]

Studies on the *prevalence* of voice disorders in the general population have yielded a wide range of results. Apparently, the primary reason for the variability in the reported prevalence is the differences in the definition for "voice disorders," as well as methodology differences between the studies.[3] Nonetheless, prevalence of voice disorders in the general population was typically reported to range between 3% and 9%, in which approximately 6% report a *present* voice disorder; more than 28% report ever having a voice problem. In addition, women report higher occurrence of voice disorder than men,[4,5] and professional voice users are at higher risk for developing (and reporting) voice disorders.[6] In Israel, the prevalence of *present* voice disorders in the general population was reported recently to be 15.8%, whereas 34% of the study's participants reported ever having a voice problem.[7] Similar to the worldwide reports on the higher prevalence of voice disorders among professional voice users, it was reported to range, in Israel, between 26%[8] and 53%.[9]

It is estimated that 25–35% of the work force can be regarded as professional voice users.[10] Voice professionals are defined as individuals who depend on the consistency of their voice quality on a daily basis as a major aspect of their professional function.[11] For these individuals, chronic or even intermittent dysphonia could create a professional predicament that would impact or harm them professionally and financially.[10] The intensive and prolonged use of voice, along with their dependence on it, makes professional voice users more vulnerable to voice disorders. Those who are also particularly dependent on the high quality and stability of their voice (eg, singers or actors) are even more sensitive to slight irregularity or reduction in voice quality and stamina.[12]

The most common adverse *vocal* symptoms reported by voice professionals include hoarseness, voice breaks, vocal weakness and fatigue,[13,14] increased effort during phonation, difficulties in producing high-pitch tones, and reduction in pitch range.[15] Associatively reported *physical* complaints include shortness of breath,[16] dry throat, laryngeal discomfort, strain, pain, and physical tension.[14] Although most of the reported

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vocal and physical symptoms could have functional or behavioral origin, chronic conditions could result in organic voice disorders. Such organic findings could include laryngeal mucosa irritation, edema,[17] benign mass lesions, or hemorrhage.[18] Indeed, it was reported that laryngeal findings (LFs) among actors include altered vocal folds' vibratory pattern, decreased mucosal wave, vocal fold edema and abnormal vascularity patterns,[17] noninfective laryngitis, asthenia, nodules, and upper respiratory infections.[19] It was also suggested that acoustic analyses of actors' voice could be characterized by high perturbation values and high noise-to-harmonic ratio values.[17]

Among voice professionals, actors stand out as a group with special voice demands that could inflict risks on their voice. The actor is often required to phonate during strenuous physical activities. Actors may also experience demanding and stressful lifestyle; traveling; long and irregular work hours; and exposure to rapid differences in ambient temperature, varying humidity conditions, and inhale irritants and allergens on stage. Actors are required to adjust to different performing scenes and cope with varying acoustic conditions, background noise, stage events, or music.[20] Furthermore, actors are expected to portray different characters (eg, young or old, unhealthy, loud, and aggressive) to meet the artistic demands of their role. The intended voice does not necessarily match the actor's natural voice and may require phonation during coughing, shouting, and screaming and similar vocal activities that would typically be considered vocal abuse. Consequently, the actor adjusts his/her voice to produce the required voice quality authentically and may introduce damaging effects to the vocal mechanism.[20,21]

Acting schools usually include in their curriculum, voice training and speech lessons to guide the beginning actors on how to preserve their voice during training years and throughout their professional career. These voice classes are given during the student's years in acting school. Consequently, students participate in acting classes and other highly demanding vocal activities before they acquire the required knowledge and techniques to preserve their voice. In one of the leading acting school in Israel, for example, first-year students are required to take on themselves a highly intensive course load, which includes many acting, singing, and movement classes. In that school, voice lessons are given only from the second year of the program. This could lead to the students taking on themselves extensive vocal loading before learning proper voice techniques and could impose a high risk for developing voice disorders right at the beginning of their professional career. In addition, many of these students have an out-of-stage lifestyle that consists of working in other jobs and having limited voice rest, which may play an additive role on their voice. Therefore, this study was aimed to explore voice characteristics of the first-year acting students in Israel, using a set of acoustic, aerodynamic, perceptual, and self-evaluative measures. This was done in an attempt to learn whether these sets of measures could provide insight into the voice differences between men and women with and without LFs within this professional population.

METHODS

Participants

After obtaining the approval of our institutional ethics committee and a written consent from all participants, 79 first-year acting school students were included in this study, as part of a 3-year project in which they are followed. The study group consisted of 55 women and 24 men, with a mean age of 24.50 years (range: 21–32 years; standard deviation: 2.11). Table 1 presents the participants' demographic information and a summary of their reported medical condition.

TABLE 1.
Demographic and Reported Medical Condition of All Participants

Participants' Information	Men	Women	Overall
Demographic			
Age (y)	25.44 (2.06)	24.19 (2.03)	24.56 (2.11)
Height (cm)	178.81 (6.40)	163.05 (7.33)	167.84 (10.12)
Weight (kg)	75.83 (13.57)	58.69 (9.08)	63.88 (13.12)
Medical			
Healthy	75.00 (18)	72.72 (40)	73.41 (58)
Allergies	37.59 (9)	29.09 (16)	31.64 (25)
Chronic condition	12.50 (3)	9.09 (5)	10.12 (8)
ENT condition	8.33 (2)	10.90 (6)	10.12 (8)
Heartburn	12.50 (3)	14.54 (8)	13.92 (9)
Hearing	20.83 (5)	7.27 (4)	11.39 (9)
Chronic cold	25.00 (6)	27.27 (15)	26.58 (21)
Medications	33.33 (8)	12.72 (7)	18.98 (15)
Operations	58.33 (14)	25.45 (14)	35.44 (28)
Consumes alcohol	83.33 (20)	67.27 (37)	72.15 (57)
Smoking	50.00 (12)	43.63 (24)	45.56 (36)

Demographic data are presented by group means (standard deviation). Reported medical condition is presented in percentage (numerical values).
Abbreviation: ENT, ear, nose, and throat.

As shown, no apparent differences were observed between men and women for most reported medical conditions. Yet, men reported more frequently than women on hearing problems (20.83% vs 7.27%), medication consumption (33.33% vs 12.72%), and history of operations (58.33% vs 25.45%). In addition, 45.56% of the acting students were smokers (men: 50.00% and women: 43.63%). This is markedly higher than the reported proportion of smokers in the general population in Israel, which is 23.3% (men: 32.0% and women: 15.1%).[22] In addition, alcohol consumption (regardless of quantity and frequency) was reported by 72.15% of participants (men: 83.33% and women: 67.27%).

Assessment

All participants were examined using a battery of evaluation procedures. These included (1) videostroboscopy, (2) acoustic analysis, (3) aerodynamic measurements, (4) perceptual evaluation, and (5) self-report. Each participant was evaluated individually, and the professionals who performed the evaluations were blinded to the purpose of the study and to the assignment of the participants to the study groups.

Stroboscopic examination was performed by a laryngologist, using an EndoStrob-DX laryngeal Stroboscope (Xion Medical GmbH, Berlin, Germany) with a rigid 70° OP 1070A laryngoscope (DCS Medical, Ltd., Ra'anana, Israel). The inclusion criterion to the LFs group was based on the identification of any LF or abnormality in this examination.

Aerodynamic evaluation was performed by a speech-language pathologist (SLP), using a PAS model 6600 (KayPENTAX, Corp., Lincoln Park, NJ). Evaluation included four predefined clinical protocols: (1) Vital Capacity, (2) Sustained Phonation, (3) Voicing Efficiency, and (4) Running Speech. Each participant performed the Vital Capacity and Voicing Efficiency protocols three times, and mean values for each measure were calculated. Values obtained from the Sustained Phonation and Running Speech protocols were based on a single performance. For the Running Speech protocol, participants were instructed to read the "Thousand Islands" Hebrew reading passage.

Acoustic analyses were performed by an SLP. Recordings were performed using a Sennheiser PC 20 headset microphone (Sennheiser Communications GmbH, Wedemark, Germany), located at a fixed distance of 7 cm from the corner of the speakers' mouth. Signal was recorded using *Goldwave*, Version 5.57 (Goldwave, Inc., Newfoundland, Canada) with a sampling rate of 48 kHz (16 bit) and saved as a monochannel WAV file. Participants were recorded while producing the vowels /a/, /i/, and /u/ repeatedly seven times in a random order. The present report consists only of the analyses of the data obtained from the vowel /a/. Acoustic analysis was performed using *Praat* 5.3 (Paul Boersma and David Weenick, University of Amsterdam, Amsterdam, The Netherlands).[23]

Perceptual evaluation was performed independently by two SLPs and a laryngologist using the Grade, Roughness, Breathiness, Asthenia, Strain (GRBAS) scale.[24] Subjective self-report was obtained from each subject using the Hebrew version of the Voice Handicap Index (VHI)[25] and a set of anamnesis questions. The full list of all protocols and measures is detailed in Table 2.

RESULTS

Based on the findings from the stroboscopy, participants were assigned into two groups: (1) LFs and (2) no laryngeal findings (NLFs). Of the 79 participants, 40 (50.63%) were diagnosed with vocal folds findings or abnormalities and were assigned to the LF group. Thirteen of the 24 participants (54.16%) from the men's group were assigned to the LF group and 11 (45.84%) to the NLF group. Twenty-seven of the 55 participants (49.10%) from the women's group were assigned to the LF group and 28 (50.90%) to the NLF group. The LFs consisted of benign mass lesions (15 cases), signs of gastroesophageal reflux disease (10 cases), ectasis (seven cases), edema (five cases), submucosal scaring (three cases), mucosal wave irregularity (three cases), and vibratory asymmetry or incomplete adduction (10 cases) (note that some participants were diagnosed with more than one finding). Group means for all measures are presented in the Appendix.

Factor analyses

Four factor analyses were performed, one for each mode of evaluation. This was deemed desired to reduce the number of statistical analyses and the probability of statistical error. In addition, it was aimed to identify measures that would merge into significant factors and differentiate between voices of participants in the LF and NLF groups, and between genders. Based on the construction of the factors in each of the four procedures, a two-way analysis of variance (ANOVA) was performed for each factor, in which Gender and Pathology were defined as the between-subject parameters, and the different factors were defined as the dependent variables.

Acoustic analyses

Table 3 presents the acoustic measures converged into three factors. Factor 1 best correlated with the frequency and amplitude perturbation measures, the two noise indices, and the autocorrelation measure. This factor was considered to represent *Regularity* of the voice signal. Factor 2 correlated most significantly with the three fundamental frequency (F_0) measures obtained from the recordings of the sustained phonation of the vowel /a/; thus it was considered as representing *F_0-variability.* Factor 3 correlated with the three F_0-related acoustic measures obtained from the glissando task and was titled *Glissando dynamic range*.

Three separate ANOVAs were performed, one for each factor. A statistically significant main effect for Group was found only for factor 1 (*Regularity*; $F(1,75) = 4.43$, $P = 0.038$) but not for the other two factors (*F_0-variability* and *Glissando*; $P > 0.05$). A statistically significant main effect for Gender was found for factor 2 (*F_0-variability*) and factor 3 (*Glissando*) ($F(1,75) = 208.61$, $P < 0.0001$; $F(1,75) = 5.81$, $P = 0.018$, respectively). No significant Gender × Group interaction was found for either of the factors ($P > 0.05$).

Aerodynamic analyses

Table 4 presents the aerodynamic measures converged into three factors. Factor 1 correlated significantly with measures of expiratory volume and phonation time, thus it was titled

TABLE 2.
The Full List of the Measures Obtained From the Acoustic, Aerodynamic, Perceptual, and Self-Evaluation Protocols

Evaluation	Task	Measures
Acoustic	Sustained /a/	Jitter, RAP, PPQ5
		Shimmer, APQ5, APQ11
		Mean autocorrelation
		NHR, HNR
		F_0 mean, maximum, minimum
	Glissando	F_0 range, maximum F_0, minimum F_0
Aerodynamic	Vital capacity	Expiratory volume
		Mean expiratory duration
		Peak airflow
	Maximum sustained phonation	Expiratory volume
		Mean F_0
		Phonation time
	Running speech	Peak expiratory airflow
		Peak inspiratory airflow
	Voicing efficiency	Power
		Resistance
		Efficiency
Perceptual	GRBAS	G—Grade
		R—Roughness
		B—Breathiness
		A—Asthenia
		S—Strain
Subjective self-report	VHI-Hebrew	VHI-total
		VHI-P (physical)
		VHI-F (functional)
		VHI-E (emotional)
	Anamnesis	Report having voice problem
		Pleased with voice
		Concerned about voice
		Amount of speech
		Speak loud at work
		ENT visit
		Miss work
		History of voice/speech therapy
		Hoarseness

Abbreviations: RAP, relative average perturbation; PPQ5, five-point period perturbation quotient; APQ5, 5-point amplitude perturbation quotient; APQ11, 11-point amplitude perturbation quotient; NHR, noise-to-harmonic ratio; HNR, harmonic-to-noise ratio; ENT, ear, nose, and throat.

Volume. Factor 2 correlated mainly with expiratory and inspiratory measures, obtained from the *Running Speech* protocol. Factor 3 correlated with the resistance, efficiency, and power measures obtained from the Voicing Efficiency protocol and was titled *Efficiency*.

Three separate ANOVAs were performed, one for each factor. A statistically significant main effect for Gender was found for factor 1 (*Volume*; $F(1,74) = 103.47$, $P < 0.0001$) but not for the *Running Speech* and the *Efficiency* factors ($P > 0.05$). Statistically significant main effect was found neither for Group nor for Gender × Group interaction for any of the factors ($P > 0.05$).

Perceptual evaluation

The five perceptual GRBAS scales converged into a single factor, as shown in Table 5. The Grade scale correlated highly with the constructed factor, whereas the Asthenia scale least correlated with it.

ANOVA was performed for the perceptual single factor. A statistically significant main effect for Group was found ($F(1,75) = 23.73$; $P < 0.0001$). Significant main effect was found neither for Gender nor Gender × Group interaction ($P > 0.05$).

Subjective self-evaluation

Table 6 presents the subjective self-report measures, obtained from the VHI and from the anamnesis questionnaire, converged into three factors. Factor 1 correlated with the four scores obtained from the VHI and the responses to the two general questions ("were you hoarse in the past year" and "how pleased are you with your voice"). This factor was titled *Self-Evaluation*. Factor 2 correlated with the participants' responses to the question regarding the history of ear, nose, and throat visits, missing work because of voice problems, and history of voice therapy. This factor was titled *Treatment*. Factor 3 correlates with the

TABLE 3.
Summary Result of the Factor Analysis Performed for the Acoustic Measures

Factor Pattern (Standardized Regression Coefficients)

Task	Measure	Factor 1	Factor 2	Factor 3
Prolonged /a/	RAP	0.92283	0.04844	−0.19897
	PPQ5	0.91851	−0.09408	−0.09158
	Jitter	0.91533	−0.02894	−0.18299
	NHR	0.91197	−0.10007	−0.12489
	Shimmer	0.75062	−0.25464	0.31542
	APQ5	0.72499	−0.26610	0.32796
	APQ11	0.68723	−0.38863	0.28837
	HNR	−0.86741	0.08615	−0.08405
	Mean autocorrelation	−0.90631	0.12005	0.09741
	Maximum F_0	0.17883	0.97314	0.12220
	Mean F_0	0.15923	0.97262	0.12520
	Minimum F_0	0.14703	0.97116	0.12749
Glissando	Glissando maximum	−0.03853	0.20613	0.84972
	Glissando range	−0.02801	0.21628	0.82528
	Glissando minimum	−0.15264	−0.00967	0.78395

Abbreviations: RAP, relative average perturbation; PPQ5, five-point period perturbation quotient; APQ5, 5-point amplitude perturbation quotient; APQ11, 11-point amplitude perturbation quotient; NHR, noise-to-harmonic ratio; HNR, harmonic-to-noise ratio; ENT, ear, nose, and throat.

participants' responses to the questions concerning the use of loud voice at work, amount of speech, concerns about voice, and whether they have a voice problem. This factor was titled *Vocal use*.

Three separate ANOVAs were performed, one for each factor. A significant main effect for Group was found for all three factors (*self-evaluation*, *therapy*, and *vocal use*; $F(1,74) = 7.01$, $P < 0.009$; $F(1,74) = 8.99$, $P = 0.003$; and $F(1,74) = 8.87$, $P = 0.004$, respectively). A significant main effect for Gender was found only for the *therapy* factor ($F(1,74) = 6.97$, $P < 0.01$). No main effect for Gender was found for the *self-evaluation* and *vocal use* factors, and no significant Group × Gender interaction was found ($P > 0.05$).

DISCUSSION

Before summarizing and discussing the main results of the factor analysis, it should be noted that approximately 50% of our first-year acting students were diagnosed with laryngeal abnormalities. Moreover, some of the participants had more than one finding. This reported that the prevalence might seem high, in comparison with the reported prevalence of 3–16% in the general population.[7,26] Yet it is in agreement with more recent reports,[27] which concluded that laryngeal abnormalities might occur rather commonly in asymptomatic voice professionals and that these findings could be accompanied by skewed acoustic measurements. In addition, because the present study regarded a variety of LFs as a single group, it does not allow for fine distinction between them.

TABLE 4.
Summary Result of the Factor Analysis Performed for the Aerodynamic Measures*

Factor Pattern (Standardized Regression Coefficients)

Task	Measure	Factor 1	Factor 2	Factor 3
Vital capacity[1] and sustained phonation[2]	Expiratory volume[1]	0.84203	0.02874	−0.18181
	Phonation time[2]	0.73939	0.19028	0.13187
	Peak airflow[1]	0.71138	−0.43188	−0.10480
	Expiratory volume[2]	0.73699	0.20741	−0.12800
	Mean pitch[2]	−0.72427	−0.16411	−0.05604
Running speech[3] and vital capacity[4]	Peak expiratory[3]	0.16595	0.75020	−0.03228
	Mean expiratory duration[4]	−0.29011	0.56923	0.18368
	Peak inspiratory[3]	−0.34345	−0.70075	0.18796
Efficiency[5]	Resistance[5]	−0.02227	−0.03322	0.81269
	Efficiency[5]	−0.01506	−0.05224	0.61089
	Power[5]	−0.00358	−0.06703	−0.47407

* The different factors were constructed from measures obtained from different measurement protocols. The superscript numbers associated with the tasks and measures indicate the task from which each measure was obtained.

TABLE 5.
Summary Result of the Factor Analysis Performed for the Perceptual Scales

Factor Pattern	
Measures	Factor
Grade	0.91763
Strained	0.77235
Roughness	0.76556
Breathiness	0.64751
Asthenia	0.42341

Table 7 presents an overview of the results of all ANOVAs performed on the constructed factors to enable a clear and simplified impression of the results.

Group differences

Of the three acoustic analysis factors, only *Regularity* differentiated between speakers with and without laryngeal abnormalities. This factor consists mainly of frequency and amplitude perturbation measures. Therefore, it is not surprising that it differentiated between subjects with and without laryngeal abnormalities. Measurements of frequency and amplitude perturbation have been shown to be higher in pathologic voices compared with normal voices.[28,29] However, it was argued that these measures could be sensitive to various factors, such as gender or phonated task, which could bias their clinical value. In light of that, the observed significant main effect for Group for the *Regularity* factor supports the validity of the analysis because our data examined men and women separately and were based on sustained phonations only.

The other two acoustic analysis factors (*F_0-variability* and *Glissando*) did not differentiate between normal and pathologic voices. It is commonly reported that many pathologic voices, and especially those associated with hypertension, are characterized by high F_0.[30,31] Nonetheless, the LF group in the present study included a wide range of vocal folds findings, which could affect phonation differently and to varying degrees. For example, this group consisted primarily not only of mild cases of laryngeal abnormality but also included a few cases of benign mass lesion or edema, which would typically lower F_0. As this project advances, we aspire to increase our sample size to allow further subcategorization of the LF group and better representation of the comparison between pathologic and normal voice. Finally, another possible explanation for this result could be related to our participants' vocal training and experience. Acting students are vocally trained on a daily basis and are required to stretch their vocal boundaries. Therefore, it is possible that such training diminishes differences in habitual pitch and diapason between those with and without laryngeal abnormalities.

The three aerodynamic factors did not differentiate between participants with and without LFs in this study. Previous literature has suggested that people with laryngeal pathologies could differ from controls in their vocal aerodynamic properties.[32] Therefore, the lack of significant group differences for either of these factors suggests that the laryngeal abnormalities found in this group were either mild or did not affect the examined aerodynamic measures. In contrast, it could suggest that the standard instrumentation and protocols used here were not sensitive enough to differentiate between our specific groups. This is reminiscent of the conclusion of Mehta and Hillman[32] that although aerodynamic properties of phonation are central to voice evaluation, the available clinical and diagnostic tools might not provide sufficient information on this facet.

The single perceptual factor that was based on the five GRBAS scales differentiated significantly between students with and without laryngeal abnormalities. This result is in agreement with numerous reports on the merit of the GRBAS for quantifying perceptual evaluation of normal versus

TABLE 6.
Summary Result of the Factor Analysis Performed for Self-Report Measures

Factor Pattern (Standardized Regression Coefficients)				
Task	Measures	Factor 1	Factor 2	Factor 3
VHI	VHI-total	0.86421	−0.18768	−0.13905
	VHI-P (physical)	0.81352	−0.07967	−0.20665
	VHI-F (functional)	0.78261	−0.17127	0.06955
	VHI-E (emotional)	0.72119	−0.26391	−0.16480
Anamnesis	Hoarseness	−0.35463	−0.13579	0.22115
	Pleased with voice	−0.63694	0.21892	0.25534
	ENT visit	0.03144	0.77197	0.01851
	Miss work	−0.20015	0.65659	−0.01277
	Voice therapy	0.03605	0.65096	0.00038
	Speak loud at work	0.11833	−0.26607	0.82789
	Have voice problem	−0.25238	0.20505	0.57530
	Concerned about voice	0.37051	−0.19361	−0.58350
	Amount of speech	−0.38839	−0.44905	−0.65347

Abbreviation: ENT, ear, nose, and throat.

TABLE 7.
Summary of Significance Levels (*P*-Values) for the Comparison Between Genders and Groups in the ANOVAs Performed on the Constructed Factors

Measures' Category	Factor	Gender	Pathology
Acoustic	Regularity	0.803	0.039*
	F_0-variability	<0.001*	0.372
	Glissando range	0.018*	0.688
Aerodynamic	Volume	<0.001*	0.577
	Running speech	0.144	0.672
	Efficiency	0.895	0.973
Perceptual	GRBAS	0.687	<0.001*
Self-report	Self-evaluation	0.758	0.009*
	Seek therapy	0.010*	0.004*
	Vocal use	0.068	0.004*

* Significant difference.

pathologic voices.[33,34] In addition, perceptual evaluation of voice is considered by many clinicians and researchers as the gold standard for voice evaluation.[35] Therefore, the fact that the two groups were identified differently by listeners implies that their voice profile is different, such that the students with the laryngeal abnormalities had, indeed, lower voice quality than the students without LFs.

The five perceptual scales of the GRBAS converged into a single factor. *Asthenia* was the one scale that correlated least with the constructed factor, whereas *Grade* correlated with it the most. This supports previous research that identified the Grade scale as the most reliable and Asthenia as the least.[36,37] It was suggested that this could be attributed to inconsistencies in the way listeners view and perceive the term "asthenia."

The three self-report factors differentiated between the students with and without laryngeal abnormalities. The *Self-Evaluation* factor, which encompasses the VHI scores, a general question on how pleased the speakers were with their voice and a hoarseness self-evaluation question, was expected to distinguish between people with and without a voice problem. It was previously shown that the VHI and the additional two questions are in good agreement and that people with a voice problem tend to rate themselves higher on these scales than controls. These results were consistent for both the original version of the VHI[38] and the Hebrew version,[25] which was used here.

People who suffer from voice disorders are expected to also be more inclined to seek professional help (as reflected by the second factor). It is also expected that people who use their voice in a more demanding manner would be more prone to develop voice disorders (as reflected by the third factor). Thus, the fact that the two latter factors (*Treatment* and *Vocal Use*) differentiated between students with and without laryngeal abnormality is not surprising. Nonetheless, most participants (in both groups) did not report on themselves as having a voice problem, and they have regularly participated in all required vocal and acting performances during their routine studies. In light of that, and based on the informal impression of these acting students, we were surprised to learn that these two factors significantly differentiated between the two groups. This lends support to the importance of the use of self-report rating scales, on top of the informal and nonstandardized evaluation, which is commonly used in most clinical settings. The use of such tools contributes to revealing information that might be concealed during an informal interview with the patient.

Gender differences

The two acoustic analysis factors that differentiated between men and women were *F_0-Variability* and *Glissando*. This was expected because both factors are constructed solely of F_0 measurements (ie, maximum, minimum, mean, and range), which are probably the most prominent, although not the only vocal feature that distinguishes perceptually and acoustically between genders.[39]

Of the three aerodynamic factors, the first one (*Volume*) significantly differentiated between men and women. This factor consists of measures of expiratory volume, peak airflow, phonation time, and mean F_0. Zraick et al[40] have recently provided normative data on aerodynamic measurements performed with the system used in the present study. They noted that the gender differences were found in a limited number of measures. The *Volume* factor, which was the only one that differentiated between genders, is based on the very same set of measures reported by them to differ between genders. Therefore, although the aerodynamic factors did not provide insight into the differences between people with and without LFs in our study, the observed gender difference demonstrates the validity of these measurements. These gender differences in expiratory volume, peak airflow, and phonation time are clearly the result of the known and well-documented physical differences in the lung volume, air consumption during speech, and power between men and women.[41] Similar to the study by Zraick et al,[40] all other aerodynamic measures did not reveal gender differences.

Of the three self-report factors, only the *Treatment* factor revealed significant gender differences, with women seeking more professional advice from a laryngologist or speech therapist than men, and missing work because of voice problems. This gender difference in medical help-seeking pattern is evidently not specific to voice disorders and definitely not specific to the present study. This trend was documented in different medical fields and is considered to result from various biological and psychological factors, which are supported by social traditions.[42] Nonetheless, this suggests that, in contrast to women, men might postpone their initial referral to a laryngeal examination and voice evaluation, and could be eventually diagnosed with more severe conditions than women, who would be diagnosed at an earlier stage of their medical/voice condition.

CONCLUSIONS

This study examined first-year acting students' voices and compared between men and women with and without laryngeal abnormalities. More than 50% of our study group was diagnosed with one or more LFs. Although most of these abnormalities can be defined as mild and although most of these students did not present themselves as having a voice problem, factor analysis demonstrates identifiable differences between the groups. Specifically, the Regularity factor, the GRBAS factor, and the three self-report factors distinguished between the groups. The only factor category that did not reveal group differences was the aerodynamic measures. This challenges the use of this tool for the evaluation of voice production within the restricted framework of our study population.

The high incidence of laryngeal abnormalities among first-year acting students, and the fact that these students had different vocal profile than their peers, stress the need for early laryngeal examination and voice evaluation of future voice professionals. The excessive vocal demands, with which these young students are expected to deal, could raise the risk of creating vocal trauma or pathology. However, slightly abnormal findings (acoustic, aerodynamic, perceptual, and/or laryngeal) could be present even among seemingly asymptomatic voice professionals. Therefore, establishing a personal baseline on a wide range of voice evaluation dimensions at an early stage in the professional career would be valuable for ongoing evaluation and follow-up along the actor's future career.

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APPENDIX 1.
Group Means (Standard Deviations) for All Acoustic Measures, Arranged by Tasks, Obtained for Both Groups and Genders

		LFs		NLFs	
Task	Measure	Men	Women	Men	Women
Sustained /a/	Mean F_0 (Hz)	131.59 (12.87)	210.89 (25.93)	118.49 (16.22)	215.41 (23.85)
	Minimum F_0 (Hz)	128.97 (13.02)	206.45 (25.51)	116.16 (16.01)	210.98 (23.00)
	Maximum F_0 (Hz)	134.58 (12.83)	215.35 (26.75)	120.61 (16.38)	218.64 (24.07)
	Jitter (%)	0.34 (0.11)	0.34 (0.17)	0.30 (0.07)	0.25 (0.06)
	RAP (%)	0.18 (0.07)	0.20 (0.11)	0.16 (0.04)	0.14 (0.03)
	PPQ5	0.20 (0.06)	0.19 (0.08)	0.18 (0.04)	0.15 (0.03)
	Shimmer (%)	2.49 (1.51)	2.25 (1.06)	2.10 (0.75)	1.97 (0.47)
	APQ5 (%)	1.53 (0.96)	1.35 (0.64)	1.29 (0.49)	1.22 (0.29)
	APQ11 (%)	1.91 (0.97)	1.56 (0.70)	1.69 (0.52)	1.40 (0.35)
	Autocorrelation (%)	0.99 (0.01)	0.99 (0.01)	0.99 (0.01)	0.99 (0.01)
	NHR (dB)	0.007 (0.003)	0.007 (0.006)	0.006 (0.003)	0.005 (0.003)
	HNR (dB)	23.68 (2.02)	24.26 (3.45)	24.80 (2.27)	24.48 (2.48)
Glissando	Minimum F_0 (Hz)	75.35 (35.39)	82.58 (50.04)	62.99 (31.34)	88.80 (38.61)
	Maximum F_0 (Hz)	605.51 (352.74)	1083.34 (648.72)	659.10 (386.43)	1105.04 (448.10)
	F_0 range (Hz)	530.16 (329.42)	1000.76 (615.96)	596.11 (361.63)	1016.23 (437.18)

Abbreviations: RAP, relative average perturbation; PPQ5, five-point period perturbation quotient; APQ5, 5-point amplitude perturbation quotient; APQ11, 11-point amplitude perturbation quotient; NHR, noise-to-harmonic ratio; HNR, harmonic-to-noise ratio.

APPENDIX 2.
Group Means (Standard Deviations) for All Aerodynamic Measures, Arranged by Examination Protocols, Obtained for Both Groups and Genders

		LFs		NLFs	
Protocol	Measure	Men	Women	Men	Women
Vital capacity	Expiration duration (s)	2.58 (0.74)	2.98 (1.40)	2.63 (0.77)	2.98 (1.43)
	Peak airflow (L/s)	4.65 (2.72)	2.66 (1.56)	4.59 (2.76)	2.79 (1.58)
	Expiration volume (L)	4.05 (1.18)	2.46 (0.59)	4.12 (1.15)	2.53 (0.59)
Maximum phonation	Mean F_0 (Hz)	125.60 (19.48)	206.73 (24.65)	124.80 (18.36)	207.72 (25.40)
	Phonation time (s)	23.46 (4.72)	15.94 (5.87)	23.64 (4.50)	16.34 (5.89)
	Expiratory volume (L)	3.64 (0.79)	2.53 (1.05)	3.66 (0.79)	2.59 (1.09)
Voicing efficiency	Power (%)	0.30 (0.17)	7.68 (0.95)	0.29 (0.17)	8.62 (0.28)
	Resistance (%)	56.21 (22.48)	60.42 (22.96)	57.42 (22.54)	61.55 (21.78)
	Efficiency (%)	873.20 (705.66)	992.14 (1216.30)	926.99 (710.09)	844.44 (786.19)
Running speech	Expiratory volume (L)	1.31 (0.45)	1.16 (0.34)	1.33 (0.46)	1.18 (0.35)
	Inspiratory volume (L)	−2.67 (0.63)	−2.40 (0.36)	−2.71 (0.60)	−2.43 (0.37)

APPENDIX 3.
Group Means (Standard Deviations) for the Five Subjective Measures (GRBAS Scale) Obtained for Both Groups and Genders

	LFs		NLFs	
Measure	Men	Women	Men	Women
Grade	0.39 (0.66)	0.32 (0.61)	0.35 (0.65)	0.27 (0.61)
Roughness	0.44 (0.59)	0.46 (0.57)	0.44 (0.44)	0.42 (0.58)
Breathiness	0.17 (0.49)	0.39 (0.53)	0.17 (0.49)	0.42 (0.54)
Asthenia	0.09 (0.29)	0.00 (0.00)	0.43 (0.21)	0.00 (0.00)
Strain	0.13 (0.34)	0.11 (0.32)	0.13 (0.34)	0.10 (0.31)

APPENDIX 4.
Group Means and (Standard Deviations) for All Self-Report Measures Obtained for Both Groups and Genders

	LFs		NLFs	
Measure	Men	Women	Men	Women
Amount speech	5.62 (1.38)	6.37 (0.88)	5.00 (1.00)	5.83 (1.04)
Voice disturb	3.07 (2.32)	4.66 (2.05)	2.72 (2.10)	2.32 (1.56)
VHI-F (functional)	5.76 (5.96)	5.81 (6.08)	3.18 (3.40)	3.39 (3.90)
VHI-P (physical)	9.84 (7.81)	13.33 (9.37)	8.18 (7.34)	6.67 (7.09)
VHI-E (emotional)	3.69 (4.51)	10.33 (10.11)	2.27 (3.31)	2.89 (3.91)
VHI-total	19.30 (16.59)	29.48 (22.90)	13.63 (12.40)	12.96 (13.41)
Satisfied	7.73 (1.39)	5.88 (2.48)	7.72 (1.34)	8.10 (1.66)
Voice problem	0.61 (0.50)	0.29 (0.46)	0.72 (0.46)	0.71 (0.46)
Miss work	0.92 (0.27)	0.69 (0.47)	0.00 (0.00)	0.96 (0.18)
Talk loud	0.07 (0.27)	0.07 (0.26)	0.18 (0.40)	0.14 (0.35)
Therapy history	0.84 (0.37)	0.51 (0.50)	0.81 (0.40)	0.82 (0.39)
Hoarse past year	0.46 (0.51)	0.33 (0.48)	0.36 (0.50)	0.50 (0.50)
ENT visit	0.69 (0.48)	0.59 (0.50)	0.81 (0.40)	0.71 (0.46)
Health problems	2.61 (1.50)	2.37 (1.14)	2.27 (0.78)	2.60 (1.22)
Allergy	0.61 (0.50)	0.66 (0.48)	0.63 (0.50)	0.75 (0.44)
Chronic illness	0.84 (0.37)	0.88 (0.32)	0.90 (0.31)	0.92 (0.26)
ENT illness	1.00 (0.00)	0.88 (0.32)	0.80 (0.42)	0.89 (0.31)
Reflux	1.00 (0.00)	0.81 (0.39)	0.72 (0.46)	0.89 (0.31)
Hearing problems	0.84 (0.37)	0.92 (0.26)	1.72 (0.46)	0.92 (0.26)
Getting cold	0.84 (0.37)	0.70 (0.46)	0.63 (0.50)	0.75 (0.44)
Medications	0.69 (0.48)	0.81 (0.39)	0.63 (0.50)	0.92 (0.26)
Operations	0.38 (0.50)	0.81 (0.39)	0.45 (0.52)	0.66 (0.48)
Smoking	0.23 (0.43)	0.51 (0.50)	0.81 (0.40)	0.60 (0.49)
Alcohol	0.15 (0.37)	0.29 (0.46)	0.18 (0.40)	0.35 (0.48)

Abbreviation: ENT, ear, nose, and throat.