Laryngoscopic and Spectral Analysis of Laryngeal and Pharyngeal Configuration in Non-Classical Singing Styles

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Summary: Purpose. The present study aimed to assess three different singing styles (pop, rock, and jazz) with laryngoscopic, acoustic, and perceptual analysis in healthy singers at different loudness levels. Special emphasis was given to the degree of anterior-posterior (A-P) laryngeal compression, medial laryngeal compression, vertical laryngeal position (VLP), and pharyngeal compression.

Study Design. Prospective study.

Methods. Twelve female trained singers with at least 5 years of voice training and absence of any voice pathology were included. Flexible and rigid laryngeal endoscopic examinations were performed. Voice recording was also carried out. Four blinded judges were asked to assess laryngoscopic and auditory perceptual variables using a visual analog scale.

Results. All laryngoscopic parameters showed significant differences for all singing styles. Rock showed the greatest degree for all of them. Overall A-P laryngeal compression scores demonstrated significantly higher values than overall medial compression and VLP. High loudness level produced the highest degree of A-P compression, medial compression, pharyngeal compression, and the lowest VLP for all singing styles. Additionally, rock demonstrated the highest values for alpha ratio (less steep spectral slope), L1-L0 ratio (more glottal adduction), and Leq (more vocal intensity). Statistically significant differences between the three loudness levels were also found for these acoustic parameters.

Conclusions. Rock singing seems to be the style with the highest degree of both laryngeal and pharyngeal activity in healthy singers. Although, supraglottic activity during singing could be labeled as hyperfunctional vocal behavior, it may not necessarily be harmful, but a strategy to avoid vocal fold damage.

Key Words: Laryngeal hyperfunction–Supraglottic activity–Laryngoscopy–Singing voice–Nonclassical singers.

INTRODUCTION

Earlier studies have suggested that supraglottic activity may not necessarily be a sign of vocal hyperfunction or harmful behavior to vocal folds, but rather a normal and even desirable muscle activity.[1–9] Titze[10] offered an explanation for the possible positive effect of supraglottic compression. The author states that the source-filter interaction and the vocal tract inertance may be increased by narrowing the epilarynx tube in an anterior-posterior (A-P) direction. Inertance is an acoustic property of the accelerating or decelerating supraglottal air mass in the vocal tract which may favorably impact the vocal fold vibration and may allow for an efficient voice production that could possibly be associated with lower effort and a more resonant and stronger sound. Therefore, this A-P narrowing could constitute a benefit for vocal fold oscillation, vocal fold adduction, and subglottic pressures required for phonation.[10–12]

Although there is evidence showing that supraglottic activity could be desirable during singing, most studies have included small sample sizes, and none has assessed specific variables that may have an impact on supraglottic behavior. In a recent work, Mayerhoff et al[13] evaluated the degree of A-P and medial supraglottic laryngeal compression in healthy opera singers of different voice classifications during different pitches, loudness levels, and phonatory tasks. Results demonstrated that A-P compression was greater in males and specifically baritones during loud voice production and with phonation of the vowel /a/. Medial compression was also greater in male subjects and specifically tenors during loud phonation, during high pitch, and while producing the vowel /a/. Moreover, A-P compression was greater than medial compression. Regarding the relationship between A-P compression and loudness, Yanagisawa et al[6] obtained similar results in classical and nonclassical singing styles. Medial compression has also been found in classical singing, and other styles.[14–16]

Considering nonclassical singing styles, belting technique has been associated with relatively closed ventricular spaces, constricted pharyngeal diameters, and epiglottis tilted over the larynx.[5–7] In a recent investigation aimed to vocally assess rock singers who use growl voice and reinforced falsetto, laryngoscopy showed that most of the participants evidenced during singing a high vertical laryngeal position (VLP), pharyngeal compression, A-P laryngeal compression, and medial compression. None of them had any major vocal fold pathology.[17] Interestingly, rock singers did not show any

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significant difference with pop singers (control group) for acoustic, perceptual, and functional assessment of speaking voice. This suggested that although rock singers presented with what appeared to be laryngeal and pharyngeal hyperfunctional, this did not seem to contribute to the presence of any major voice disorder.

Although earlier studies have demonstrated that supraglottic activity may not be pathologic during classical and nonclassical singing, they have not compared different singing styles produced by the same subjects. In addition, most of them have only evaluated laryngeal compression, not other features such as VLP or pharyngeal compression. The present study aimed to assess three different singing styles (pop, rock, and jazz) with laryngoscopic, acoustic, and perceptual analysis in healthy singers at different loudness levels. Special emphasis was given to the degree of A-P laryngeal compression, medial laryngeal compression, VLP, and pharyngeal compression. This work is a continuation of the recent investigation conducted by Mayerhoff et al.[13]

METHODS

Participants

Informed consent was obtained from 20 female pop singers. The average age of this subject set was 27 years, with a range of 25–31 years old. Inclusion criteria for this study included: (1) no history of voice problems in the past year, (2) no vocal fold pathology at the time of examination, and (3) at least 5 years of formal nonclassical singing training. None of the participants reported a hearing impairment. Although 20 subjects were recruited, eight of them did not meet the inclusion criteria because of vocal fold pathology found at the time of laryngeal endoscopy. Therefore, only 12 were included in the analysis. The average length of voice training was 8 years, with a range of 5–10 years. Participants were recruited from various vocal bands and conservatories. All were asked to undergo rigid videostroboscopy (Digital videostroboscopy system RLS 9100-B; KayPENTAX, Lincoln Park, NJ) to confirm the absence of laryngeal pathology. Flexible laryngoscopy (Olympus ENF type p4; Olympus, Center Valley, PA) with specific voice singing tasks (see below) was also performed to assess supraglottic activity during singing. Endoscopic laryngeal examinations were performed by three laryngologists who are coauthors of the present study (A.L., C.O., and P.C.). Intranasal topical anesthesia was used during transnasal endoscopy for all subjects. Topical anesthesia was used during rigid laryngeal endoscopy procedure only when needed because of gag reflex. This study was reviewed and approved by the University of Chile, School of Communication Sciences and Disorders Review Board.

Singing phonatory tasks

During the transnasal endoscopic examination, each participant was instructed to sing the song “Happy Birthday” in three different styles (pop, rock, and jazz). Participants were asked to produce each singing task at three loudness levels (medium, high, and low). Loudness was subjectively controlled by the singers and experimenters. The musical key of “Happy Birthday” was adapted to each singer’s vocal comfort. Participants were required to keep the same musical key during all singing phonatory tasks. This was also perceptually controlled by experimenters. All subjects were also strongly instructed to make vocal differences between singing styles and loudness levels. The flexible endoscope was placed near the tip of the uvula during singing. This position allowed a full view of the pharynx and larynx. The placement was set by securing the fiberscope against the alar cartilage of the nose with the laryngologist’s finger. A steady placement of the fiberscope is crucial because observation of laryngeal height adjustments and other laryngeal configurations can be affected by movement of the endoscope.

Visual evaluation of laryngoscopic samples

Four blinded judges (speech-language pathology graduate students with experience in singing voice and laryngeal endoscopic assessment), were asked to review the laryngoscopic examinations and rate the degree of A-P laryngeal compression, medial laryngeal compression, pharyngeal compression, and VLP on a 100 mm visual analog scale. To standardize the rating parameters and rating scales, the four judges participated in a 1-hour training session in videolaryngocopy examinations. For VLP, 1 = very low, 100 = very high; for pharyngeal compression, 1 = very wide, 100 = very narrow; for medial laryngeal compression, 1 = very open, 100 = very narrow; and for A-P laryngeal compression, 1 = very open, 100 = very narrow. All sound was removed from video recordings. Each laryngoscopic examination could be reviewed as many times as desired. A total number of 108 video samples (12 subjects × three singing styles × three loudness levels) were obtained. Additionally, 20% of samples were randomly repeated to determine whether judges were consistent in their perceptions (intrarater reliability analysis).

Audio recordings

All participants were recorded when performing the same singing phonatory tasks as during laryngoscopy (to sing “Happy Birthday” with three different styles at three different loudness levels). The duration of each recording session was approximately 15 minutes. A Focusrite Scarlett 8i-6 USB audio interphase (Focusrite Audio Engineering, High Wycombe, UK) and a Rode condenser microphone, model NT2-A (Rode, Long Beach, CA) were used to capture the voice samples. This microphone was selected on the basis that the manufacturer’s specifications include a flat frequency response from 20 to 20 000 Hz. The microphone was positioned 30 cm from the mouth of the participants who remained standing. Recording took place in an acoustically treated room and samples were recorded digitally at a sampling rate of 44 kHz and 16 bit. The capture and recording of voice signals were made using the software *Protools 9.0* (Avid Corporation, Burbank, CA). Audio signal was calibrated using a sustained vowel for further sound level measurements. The equivalent level (Leq) of this reference sound was measured with a sound level meter (Brüel & Kjær, model 2250; Brüel & Kjær Sound & Vibration

Measurement, Nærum, Denmark); also positioned at a distance of 30 cm from the mouth. Participants were not asked to control the vocal intensity because it could interfere negatively with the interpretation during singing. However, sound level was measured for further sound level analysis as previously mentioned. Samples were edited with the software *Sony Vegas, version 7.0* (Sony Creative Software, Middleton, WI).

Acoustical analysis

Acoustical analysis with longterm average spectrum (LTAS) was performed. The acoustical variables in this study were (1) the energy level difference between the F1 and F0 regions (L1–L0), that is, the energy level difference between 300–800 Hz and 50–300 Hz, which provides information on the mode of phonation; (2) the energy level difference between 1–5 KHz and 5–8 KHz, which provides information about glottal noise (breathy voice quality); (3) the alpha ratio, which is the energy level difference between 50–1000 Hz and 1000–5000 Hz, which provides information on the spectral slope declination; and (4) Leq, which gives an average of intensity (dB) over a long time window.

The LTAS spectra for each subject were obtained by *Praat software*, version 5.3.60 (Institute of Phonetic Sciences of the University of Amsterdam, The Netherlands). For each sample a bandwidth of 100 Hz and Hanning window were used. Before performing LTAS analysis, unvoiced sounds and pauses were eliminated from the samples by *Praat software* using the pitch corrected version with standard settings. Moreover, the amplitude values of the spectral peaks were normalized to control for loudness variations between subjects. This process was accomplished automatically by assigning the intensity of the strongest partial a value of zero and each subsequent partial a proportional value compared with this peak intensity.

Auditory perceptual evaluation

All recorded audio samples (108 samples) were perceptually assessed by the same four external raters that performed the laryngoscopic analysis. Additionally, 20% of the samples were randomly repeated to determine whether the judges were consistent in their perceptions (intrarater reliability analysis). The order of recordings was randomized to avoid recognition of any pattern. To standardize the rating parameters and rating scales, the four judges participated in a 1-hour training session in auditory perceptual assessment. Perceptual assessment was performed on a 100 mm visual analog scale. The auditory perceptual analysis was carried out using an adaptation of the Bele protocol developed to perceptually assess professional voices.[18,19] The perceptual variables were defined as follows: resonant voice quality: the extent to which the voice sounds resonant (0 = not resonant at all, 100 = very resonant); vocal color: the chief auditory correlate of vocal tract formant values (0 = dark color, 100 = bright color); voice placement: the extent to which the voice sounds forward (0 = backward, 100 = forward); loudness: the chief auditory correlate of sound pressure level of speech (0 = very weak, 100 = very loud); vocal onset: auditory perception of hardness of the phonation onset (0 = soft, 100 = hard); and hyperfunctional quality: auditory perception of pressed voice quality (0 = hypofunctional, 100 = hyperfunctional). Raters could replay each sample as many times as they wanted before making their determination and moving on to the next recording. The evaluation was performed in a quiet room using a high quality headphone (Bose AE2; Bose Corporation Framingham, MA). All the listeners reported normal hearing.

Statistical analysis

Descriptive statistics such as mean and standard deviation were calculated. Using a multilevel mixed effects model, intraclass correlation coefficients (ICC) were obtained to evaluate the concordance between and within judges, controlling for laryngoscopic variable, perceptual evaluation, and singing style. If the agreement was adequate ($ICC > 0.5$), the values given by each judge were averaged for each individual for further analysis. Analysis of variance was used to assess whether there are differences for each variable (laryngoscopic, acoustic, and perceptual) by singing style. A t test to compare overall laryngoscopic variables differences was also used. Finally, Pearson correlation coefficient to evaluate correlation between variables was used. All analyses were made using *Stata 12.1* (StataCorp. 2011. College Station, TX: StataCorp LP). A P-value < 0.05 was considered statistically significant and all P-values were two-sided.

RESULTS

Reliability analysis

Agreement between judges ($ICC = 0.67$, $P = 0.002$) and within each ($ICC = 0.72$, $P = 0.001$) for the laryngoscopic analysis was good. In perceptual analysis, poor agreement was obtained, both between and within judges ($ICC = 0.37$, $P = 0.091$ and $ICC = 0.29$, $P = 0.189$, respectively). This was because of dissimilar evaluation by one of the judges (poor intrarater agreement), so with this outlying judge removed from analysis, we obtained adequate final consistency ($ICC = 0.77$, $P = 0.005$).

Laryngoscopic variables

Laryngoscopic results are displayed in Figures 1–4. In all these figures, the red line represents change in mean values for each variable. All laryngoscopic variables evidenced significant differences ($P < 0.0001$) for all singing styles. Figure 1 illustrates the results from the A-P laryngeal compression. Rock evidenced the greatest degree of A-P compression, whereas jazz the lowest one. Results from medial laryngeal compression and VLP are displayed in Figures 2 and 3 respectively. Similar results were found for these variables. Rock demonstrated the highest degree of change, whereas jazz obtained the lowest one. Results from pharyngeal compression are shown in Figure 4. Rock was the style which demonstrated the most constricted pharynx, whereas pop the widest pharynx. Moreover, overall A-P laryngeal compression scores demonstrated significantly higher values than overall medial compression and VLP scores. Additionally, statistically significant differences between the three loudness levels were also found for all laryngoscopic parameters. High loudness

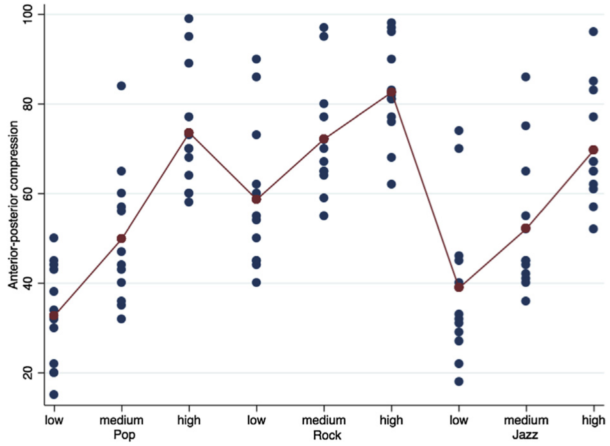

FIGURE 1. Degree of (A-P) laryngeal compression by singing style and loudness level.

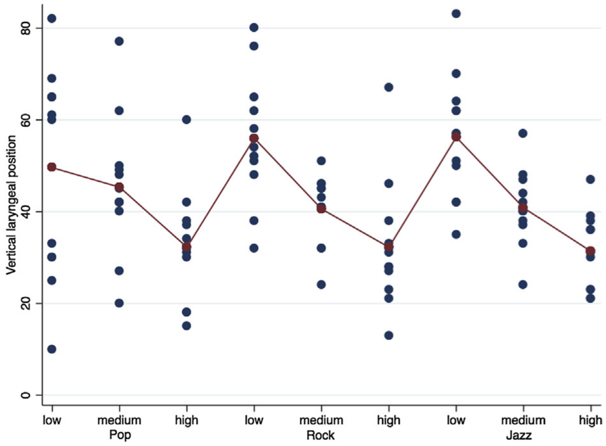

FIGURE 3. VLP by singing style and loudness level.

produced the highest degree of A-P compression, medial compression, pharyngeal compression, and the lowest VLP for all singing styles.

Spectral variables

Figures 5–7 illustrate the results from all acoustic parameters. In all these figures, the red line represents change in mean values for each variable. There was a significant difference ($P < 0.0001$) between all singing styles. For alpha ratio (Figure 5), rock showed the highest value (less negative or more positive numbers), whereas jazz evidenced the lowest alpha ratio (more negative numbers). Regarding L1-L0 (Figure 6), rock obtained the highest value, whereas pop the lowest one. Leq demonstrated the highest values in rock, whereas it showed the lowest values for pop (Figure 7). No significant differences were obtained for 1–5/5–8 KHz ratio when comparing singing styles. Moreover, statistically significant differences between the three loudness levels were also found for three of the four acoustic parameters. High loudness level produced the highest degree alpha ratio, L1-L0, and Leq for all singing styles. There was no difference for 1–5/5–8 KHz ratio regarding loudness.

Auditory perceptual variables

Results from perceptual analysis are summarized in Table 1. Statistical significant differences ($P < 0.0001$) considering singing styles and loudness levels were obtained for loudness, vocal onset and hyperfunctional voice quality. No differences were observed in resonant voice quality, vocal color, and voice placement.

Correlation analysis

The correlation analysis was as follows between Leq and L1-L0 ratio, $r = 0.76$ ($P = 0.0036$); alpha ratio and 1–5/5–8 KHz ratio, $r = -0.71$ ($P = 0.0085$); medial compression and L1-L0, $r = -0.65$ ($P = 0.0218$); loudness and L1-L0, $r = 0.68$ ($P = 0.0139$); loudness and Leq, $r = 0.87$ ($P = 0.0002$); alpha ratio and hyperfunctional voice quality, $r = 0.61$ ($P = 0.0326$); 1–5/5–8 KHz ratio and hyperfunctional voice quality, $r = -0.57$ ($P = 0.0489$); vocal onset and hyperfunctional voice quality, $r = 0.61$ ($P = 0.0330$). The rest of the combinations among variables did not show significant correlation.

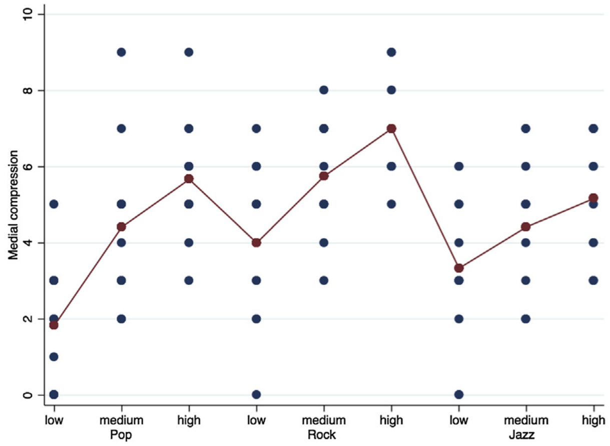

FIGURE 2. Degree of medial laryngeal compression by singing style and loudness level.

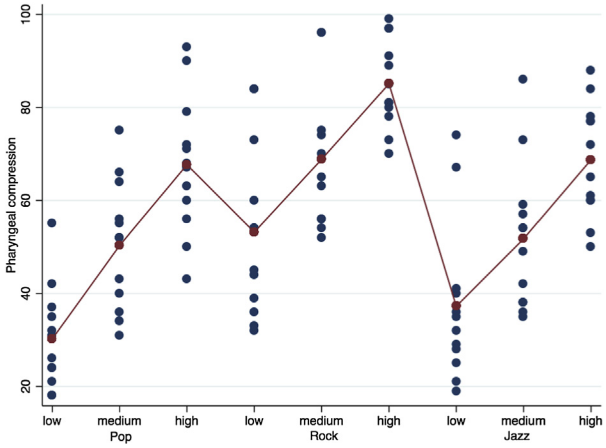

FIGURE 4. Degree of pharyngeal compression by singing style and loudness level.

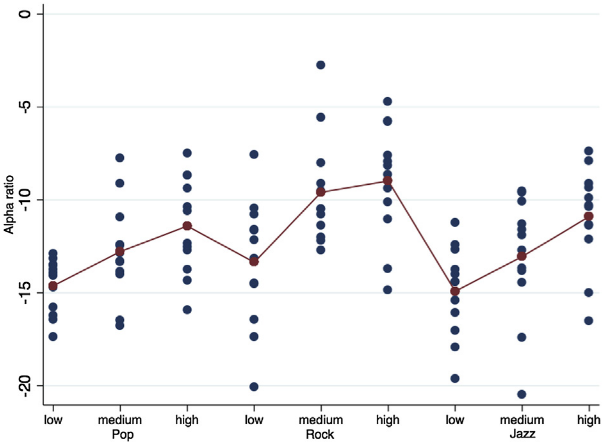

FIGURE 5. Alpha ratio values by singing style and loudness level.

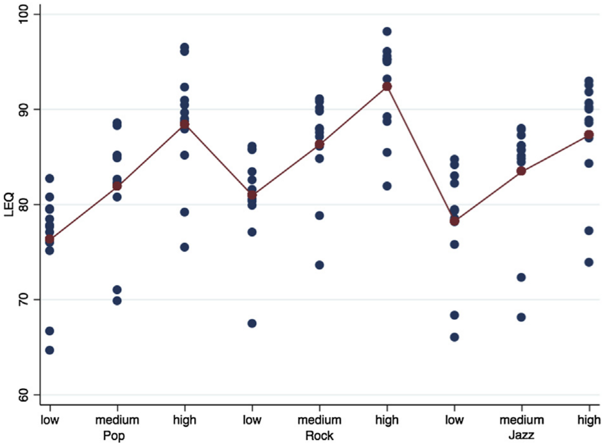

FIGURE 7. Leq values by singing style and loudness level.

DISCUSSION

The present study was conducted to assess different nonclassical singing styles in healthy singers during different loudness levels. Special emphasis was given to laryngoscopic variables (A-P laryngeal compression, medial supraglottic laryngeal compression, VLP, and pharyngeal compression), however acoustic and perceptual values were also evaluated. Findings showed that the voice is apparently used in different manners in different styles of singing.

Laryngoscopic variables

A-P and medial supraglottic compression have been shown as a common larygoscopic feature in well vocally trained singers. Our findings are in line with those earlier results. Regarding differences between styles, rock demonstrated the highest degree of activity for all laryngeal and pharyngeal variables. Guzman et al[17] obtained similar outcomes in a study performed with rock singers with a high degree of observed A-P and medial compression. Our results also showed the highest degree of VLP and pharyngeal compression in rock compared with the rest of the singing styles. This implied a high larynx and a narrow pharynx. Rock singing was characterized by the same laryngoscopic features in Guzman et al[17] study. Previously, Borch et al[20] found a high degree of supraglottic activity, including the aryepiglottic folds, anterior part of the arytenoid mucosa, and ventricular folds in rock singers. An earlier investigation performed in nonclassical styles during production of growl voice also showed simultaneous supraglottic activity during phonation.[21] High degree of perceptual vocal effort compared with other styles has been attributed to rock singing.[22] Results from perceptual assessment in our work are concordant with previous ones. The high degree of both laryngeal and pharyngeal activity is a possible explanation. As previously stated, this may not, however, necessarily constitute a detrimental behavior for vocal health. Titze[10] has stated that some laryngeal constriction during voicing could contribute to a more economic voice production due to increased vocal tract inertance.

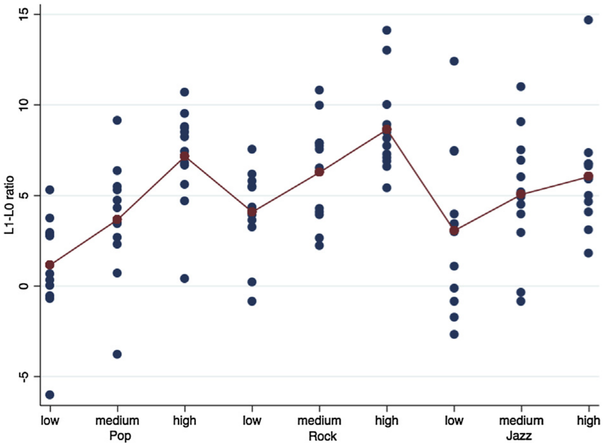

FIGURE 6. L1-L0 values by singing style and loudness level.

Our findings showed that overall A-P compression was significantly higher than overall medial laryngeal compression, the latter being about 10 times lower. This may suggest that false vocal fold approximation is not as important as aryepiglottic narrowing during singing voice in healthy subjects. Possibly a higher activity of false vocal folds could be found in pathological voices, specifically in individuals diagnosed with hyperfunctional voice disorders. Mayerhoff et al[13] found similar outcomes when comparing medial and A-P laryngeal compression in healthy opera singers.

Loudness level affected significantly the degree of laryngeal and pharyngeal activity. High loudness produced the highest degree of laryngeal A-P compression, laryngeal medial compression, and pharyngeal compression. Data related to supraglottic compression from our findings are in agreement with those observed by Mayerhoff et al[13] Authors indicated that both the degree of medial and A-P compression was greater during loud phonation. These results were observed during both sustained vowel and connected singing productions. Similarly, in an investigation conducted to assess supraglottic configuration in different singing voice qualities, greater A-P laryngeal compression was found when subjects performed loud phonation and during the three loudest voice qualities: belting, twang, and opera.[6] The rest of previous studies have evaluated supraglottic activity only during comfortable loudness.[1,3,8]

TABLE 1.
Values for Perceptual Assessment, by Singing Style and Loudness Level

	Pop			Rock			Jazz			
Perceptual Features	Low	Medium	High	Low	Medium	High	Low	Medium	High	*P* Value
Loudness	25.33 (7.59)	42 (7.89)	54.91 (12.85)	33.91 (9.83)	54.66 (7.42)	69.08 (10.29)	33.25 (12.23)	46 (9.75)	53.33 (12.91)	<0.0001
Vocal onset	25.58 (7.97)	37.66 (9.83)	47.58 (16.95)	32.08 (9.42)	51.66 (8.97)	61.25 (13.47)	31.33 (11.09)	39 (13.90)	49.16 (14.55)	<0.0001
Resonant voice quality	59.333 (8.62)	58.58 (11.71)	63.25 (17.32)	48 (17.41)	63.08 (10.25)	61.25 (15.10)	54.25 (13.71)	56.41 (13.64)	61.91 (12.28)	0.1397
Vocal color	60.66 (10.99)	56.75 (12.12)	60.91 (17.40)	47.66 (17.67)	57.08 (10.97)	61.33 (13.86)	52.5 (13.46)	55.25 (12.01)	61.41 (11.38)	0.1849
Voice placement	59.41 (6.08)	54.25 (10.84)	55.58 (13.50)	40.25 (18.13)	50.58 (17.41)	47.91 (20.44)	51.25 (9.71)	51.5 (10.66)	55.5 (10.02)	0.0638
Hyperfunctional quality	20.16 (6.23)	30.33 (9.30)	46.16 (15.49)	30.5 (11.78)	48.08 (11.54)	62.75 (16.14)	27.08 (10.95)	38.33 (12.01)	45.66 (10.99)	<0.0001

Intensity level also affected the VLP in all singing styles, being lower in loud phonation and higher during soft productions. There are no previous investigations assessing VLP in different singing styles produced by the same subjects. However, it has been demonstrated that a high VLP is present during most nonclassic styles, for example, belting. Sundberg et al[23] pointed out that belting (typically used in most contemporary commercial singing) involves an elevated larynx. Schutte et al[24] reported that belt singing is characterized by tracking of the second harmonic by the first formant. It was shown that a high VLP was needed to get that resonance strategy. Similar observations have been reported by Bourne and Garnier.[25] In a recent work evaluating resonance strategies in rock singers during reinforced falsetto at high pitches, vocal tract shortening was seen because of a high VLP.[26] A lower VLP during loud phonation was observed by Guzman et al in a study designed to assess several laryngoscopic variables during different vocal exercises in habitual, loud, and soft voice productions. In this case, however, data were not obtained from healthy singers, but dysphonic subjects. It seems that no matter the type of participants, intensity level has an impact on VLP (lowering) during voicing. Possibly, laryngeal lowering during loud phonation acts as a protecting factor.

The relationship between supraglottic activity and loudness level might be bidirectional. A greater A-P and medial compression could be caused by loud phonation possibly because of vocal effort, which would be potentially harmful to the phonatory mechanism. On the other hand, it is also possible that supraglottic compression contribute to loudness level, vocal brilliance, and easy voice production.[6,27,28] This is supported by the fact that aryepiglottic compression causes a concentration of spectral energy around 3 kHz, which in turn, would increase the overall acoustic energy.[9] Sundberg[9] suggested that when the cross-sectional area in the pharynx is at least six times wider than that of the laryngeal tube opening, the epilaryngeal tube is acoustically unlinked from the rest of the vocal tract acting as a separate resonator. Therefore, an extra formant would be added to the vocal tract transfer function. Recently, in a computerized tomography study it was found that certain types of vocal exercises might contribute to a large ratio between pharyngeal and epilaryngeal tube areas.[29] Similar findings were obtained in an investigation performed with subject diagnosed with hyperfunctional dysphonia.[30] Earlier investigations have demonstrated that a spectral prominence near 3 kHz could also be obtained by other vocal tract strategies.[31–33] The present study not only showed the highest values of Leq in rock singing, but also the same style demonstrated a perceptually louder voice compared with the rest of styles. Supraglottic activity could have contributed to the increased Leq and sonority.

Spectral variables

Results revealed that rock obtained the highest values (less negative or more positive numbers), whereas jazz evidenced the lowest values (more negative numbers) for alpha ratio. The alpha ratio, or difference between 50–1000 Hz and 1000–5000 Hz, provides information on the spectral slope declination. It was initially proposed by Frokjaer-Jensen and Prytz[34] that a low value (steeper spectral slope) would indicate that lower harmonics dominate the spectrum and the curve drops sharply more, and when these values are high, the slope is less pronounced. In other words, a high value of alpha ratio means that there is less difference between the energy of the lower and higher harmonics. Because our findings also demonstrated the highest values of Leq in rock style, the changes evidenced in alpha ratio are likely due to a total sound level increment, that is, due simply to a louder voice. Previous studies have demonstrated that intensity is not linearly correlated to the spectral envelope; an increase in sound level does not correspond to the same increase in decibels (dB) at all frequencies of the spectrum.[35] When increasing sound pressure level, the gain in dB in the region of high frequencies is greater than in region of low frequencies.[36–39] Therefore, alpha ratio in our study probably obtained the highest value (less step spectral slope) in rock style because of sound level variation during singing.

Our findings also showed that rock style obtained the highest value of L1-L0, whereas pop obtained the lowest one. L1-L0 (energy level difference between the first formant and fundamental frequency) provides information on the mode of phonation. Earlier studies have reported that a strong L0 (energy of F0) and low L1 (energy of F1) are present in the spectrum of breathy voices, whereas a weak L0 and strong L1 in strained voice, indicating respectively hypoadduction and hyperadducion of the vocal folds.[40,41] Sundberg et al[42] and Master et al[43] have demonstrated similar findings. Hence, participants in our study likely produced a more pressed voice (more glottal adduction) during rock singing compared with pop and jazz. In addition, two perceptual parameters that are related to the degree of vocal effort (vocal onset and hyperfunctional voice quality) obtained the highest values during rock singing compared with the other styles. Moreover, supporting these data, it is important to notice that a positive correlation between Leq and L1-L0 was found. Possibly, a higher glottal adduction was needed to produce more vocal intensity. These findings are also linked to the fact that positive correlation between sonority and L1-L0 was found.

Data showing the highest degree of L1-L0 in rock (highest glottal adduction), are in line with a previous investigation aimed to describe voice function of four nonclassical styles of singing: Rock, Pop, Soul, and Swedish Dance Band.[22] Outcomes evidenced that the highest values of subglottal pressure, closed quotient, and perceptually pressed voice were presented in rock singing. This later was objectively corroborated by the lowest normalized amplitude quotient value, that is, the ratio between the flow pulse amplitude and the product of period and maximum flow declination rate.[22] Normalized amplitude quotient has been found to decrease with increasing degree of phonatory pressedness.[44] Similar signs of vocal hyperfunction were also found in rock singing by Borch et al.[20]

Although the correlation analysis did not show correlation between alpha ratio and L0-L1, earlier investigations have reported a relationship between these spectral features in professional voice users.[45,46] An increase of spectral energy in the high region can be compatible with a voice produced with greater vocal adduction and also with a voice that is richer in harmonics (resonant voice). In other words, the two spectral parameters are parts of the same physiologic concept, glottal resistance. As the glottal resistance varies, these two spectral parameters should change in a related way. Master et al[46] showed a positive correlation between the alpha ratio and the L1-L0. Authors pointed out that this information reflects the relation between phonation mode and amplitude of the harmonics in the high-frequency region.

CONCLUSIONS

Laryngeal and pharyngeal supraglottic activity is commonly observed in healthy and well-trained singers. Rock singing seems to be the style with the highest degree of both laryngeal and pharyngeal activity. Intensity level has an impact on laryngeal A-P, laryngeal medial, pharyngeal compressions, and VLP during voicing. Supraglottic activity during singing may be not necessarily a hyperfunctional behavior, but a strategy to avoid vocal fold damage while producing the desired voice quality.

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