Comparative Analysis of Vocal Intensity and Aerodynamic Parameters between Singers and Non-Singers

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Abstract

While subglottal pressure, which is an aerodynamic parameter of sound, is a driving force for phonation, it is the primary factor in increasing sound intensity. The purpose of this study is to investigate the relationship between the aerodynamic parameters of sound and sound intensity between individuals who are singers and those who are not. The study included 20 volunteer male and female opera singing students who had received vocal training and did not have any voice-related pathologies and 20 male and female medical students who had not received any vocal training. As aerodynamic components, the subglottal air pressure, subglottal airflow and sound pressure level data of the participants were collected by using an Aero view Pro Phonatory Aerodynamics System kit. Estimated subglottal aerodynamic measurements were taken by using a Rothenberg mask. The sound pressure levels were additionally measured by a Sound Level Meter (2240 B&K), and the results of the two methods were compared. For the measurements, the individuals were asked to vocalize the plosive consonant of "pa" in an anechoic room. Subglottal airflow was higher in the students who had not received vocal training (1.96 ± 0.54) in comparison to the opera singing students (1.48 ± 0.31) ($p < 0.05$). Subglottal air pressure was higher in the students who had vocal training (14.36 ± 2.99) in comparison to those who did not have vocal training (11.32 ± 3.47) ($p < 0.05$). The sound intensity levels of those who had vocal training (108.53 ± 3.48) were higher than those who did not have vocal training (101.43 ± 4.52) ($p < 0.05$). The mean sound intensity check measurement value was also higher in the group with vocal training ($p < 0.05$). It was confirmed by data that an increase in subglottal pressure is a predictor of an increase in sound intensity. Subglottal airflow had a constant continuity, and it did not seem to be effective in changing sound intensity. In addition, the mean correlation between subglottic pressure and SPL was found to be the 0.85 coefficient. Singing teaches how to use the laryngeal structures effectively in an aerodynamics sense.

Introduction

Breath training is important for opera singers who have received professional voice training. Vocal intensity and control of this intensity in vocal artists and opera singers require a special training. Subglottic pressure is both the primary driving force for voice production and the primary variable in controlling vocal intensity. The expiratory air from lungs creates a longitudinal subglottic pressure wave with laryngeal airway resistance and severity of glottic closure to form glottal vibrations. This pressure wave is modulated by plica vocalis and thus the human voice we hear is produced [1]. As the closure time of plica vocalis increases, the time for enabling the pressure to rise in the bottom increases and thus the intensity of the voice produced will increase. Sound pressure level is the level of audible frequency in dB for the human ear. The increase of vocal intensity due to an increase in subglottic pressure during natural speech also increases the Fundamental Frequency (FO) [2]. The active and passive contractions of the chest and abdominal walls during voice speech create a subglottic pressure that exceeds the closing force of plica vocalis, and increase vocal intensity [1]. The combination of the aerodynamic properties of larynx and the vibration properties of plica vocalis determines the characteristics of voice sound production in trained and untrained voices [1]. Singers endeavour to have voice control that is not affected by volume changes, as it is necessary to synchronize vocal intensity and FO with a perfectly controlled subglottic pressure at broad intervals during singing. In particular, as opera singers sing songs loudly at a wide range of pitches, it is even more important for them to use subglottic pressure effectively. Sundberg et al. [3] reported that there is highly systematic relations between Ps and various flow glottogram parameters and they thought professional singers are likely to develop a particularly systematic control over phonation.

This study aims to examine the effect of vocal aerodynamic parameters on vocal intensity level of both singers who have received opera and voice training and non-singers without such training in order to determine the effect of opera and voice training on singing at high vocal intensity.

Materials and Methods

The study sample consisted of 40 volunteers aged between 18-32 without voice pathology, including 20 students from Opera and Voice Department (10 males and 10 females) and 20 medical

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Table 1: Overall means of aerodynamic parameters and SPL values.

Variables	Number	Mean	SD	Min.	Max.
Air flow	40	1.72	0.5	1.03	2.79
Air pressure	40	12.84	3.55	7.61	20.4
SPL	40	105	5.4	88.4	114
SPL 2	40	106.5	4.2	98	114
Age	40	21.9	2.9	18	32

SD: Standard Deviation; Min: Minimum; Max: Maximum.

faculty students (10 male and 10 female) who have not received vocal training. Those who have at least 2 years of opera-voice training and those who still receive are grouped as singers. The non singer group was formed using medical faculty students who voluntarily participated in the study and had previously no voice training and singing experience. The study was approved by the Faculty of Medicine Clinical Research Ethics Committee at Çukurova University. After the participants were informed about the study, their laryngeal and phoniatic examinations were performed in the Department of Otorhinolaryngology, Faculty of Medicine, Çukurova University. Then those with voice pathology and respiratory tract infection were excluded from the study. The study was conducted using the non smoker participants with no history of voice or laryngeal disorders. After the participants' consents were received using the informed consent form, the relevant measurements were performed. The estimated subglottic air pressure, subglottic airflow and Sound Pressure Level (SPL) data were collected using the Aero view Pro Phoniatory Aerodynamics System (Glottal Enterprises 162, Syracuse, NY) (<http://www.glottal.com/>) through intraoral way with the Rothenberg mask (Glottal Enterprises, model MS 100; Rothenberg, 1977). The oral airflow and air pressure data were measured by means of a short catheter placed in the mouth through the mask, using transducers (PT-2E, PT-25, Glottal Enterprises). One tip of the catheter was placed behind the teeth by passing from the lips of the person to the oral cavity, and the other tip was connected to a separator pressure transducer with a flat frequency that responded to approximately 30 Hz. For performing proper measurements, participants were asked to give a vocalization of "pa", a plosive vowel consonant, at loud voice following a deep breathing in an echo-free room. The frequency of the syllable index was set to 2.5-4.0 per second in the monitored graphical records, and the data with the best graphical curve were recorded. The values of estimated subglottic airflow, air pressure and sound pressure level were recorded as numerical data. For the numerical calculation, the best curve and at least three other (or five recommended) curves were selected with reference to the midpoint of each pressure curve

on the graph. The level of vocal intensity measurement records were taken in an anechoic room with minimal ambient noise, using the sound level meter 2240 B&K (www.bksv.com) (Bruel and Kjaer GmbH, Bremen, Germany) with condenser microphone. During the recording, participants were asked to keep the microphone at a 30 cm distance from the mouth and at an angle of 90 degrees. The distance and angle were carefully observed by the researcher. They were asked to vocalize /a/ for 30 seconds at maximum level for voice recording. The C frequency weighing parameter was used to determine the maximum sound pressure level. The microphone jack was connected to the Bruel & Kjaer Microphone Amplifier Type 2603 A with linear weighting adjustment. Audio recording tapes were obtained using the TEAC recorder (TEAC RD 200 PCM, US Instrument Services, South lake, TX). The records were taken at a print speed of 25 mm/s, using the Graphic Level Recorder Type 2305.

Statistical Analysis

The SPSS Windows version 24.0 package program (Quarry Bay, Hong Kong) was used for statistical analysis and $p < 0.05$ was considered statistically significant. For the variables of independent data in two groups, the student t-test was used to analyze the data with normal distribution, whereas the Mann-Whitney U test was used to analyze the data without normal distribution. In addition, the chi-square test was used to evaluate the relationship between two independent variables at the categorical measurement level. The Pearson correlation coefficients were calculated to determine the linear relationship between numerical variables. The beta coefficients were estimated with univariate linear regression analysis.

Results

The participants' mean age was (21.9 ± 2.9) (Table 1). A statistically significant difference was found between singers and non-singers with respect to subglottic airflow and air pressure from aerodynamic parameters (Table 2). The mean of subglottic airflow values was found to be higher in non singers (1.9 ± 0.54) than in singers (1.48 ± 0.31) ($P = 0.005$). However, the mean of subglottic air pressure values was determined to be higher in singers (14.36 ± 2.99) than in non singers (11.32 ± 3.47). ($P = 0.005$). Similar results were obtained for the variable of sound pressure level. The mean level of voice intensity determined using the Aero view Pro Phonatory Aerodynamics System was found to be higher in singers (101.53 ± 3.48) than in non singers (108.53 ± 3.48) ($P = 0.001$). The mean of voice intensity control measurements recorded using the Bruel & Kjaer Microphone was also found to be higher in singers ($P = 0.001$). A similar relationship was also observed for the variable of age ($P = 0.001$). No statistically significant difference was found between singers and non singers

Table 2: The means of aerodynamic parameters and SPL values of singers and non singers, and related analysis results.

Variables	Singers with vocal training (n= 20)	Non singers without vocal training (n=20)	Test Statistics	P
	Mean $\pm$ Standard Deviation	Mean $\pm$ Standard Deviation		
Air flow	1.48 ± 0.31	1.96 ± 0.54	$z = -1.948$	0.005*
Air pressure	14.36 ± 2.99	11.32 ± 3.47	$z = -2.787$	0.005*
SPL	108.53 ± 3.48	101.43 ± 4.52	$t = 5.557$	0.001*
SPL 2	109.2 ± 3.00	103.8 ± 3.53	$t = 5.209$	0.001*
Age	23.7 ± 2.60	20.05 ± 1.73	$z = -4.395$	0.001*

*($p < 0.05$), t; Student t test; z; Mann Whitney U test.

with respect to gender category ($P > 0.05$). There was a moderate positive correlation between subglottal air pressure and SPL ($r = 0.562$, $P = 0.001$) (Graph 1). According to univariate linear regression analysis, 56.2% of the variation in SPL was explained by air pressure, indicating a correlation with the 0.85 coefficient in the SPL values due to the increase in subglottal air pressure. Similarly, there was a moderate positive correlation between subglottal air pressure and SPL2 ($r = 0.577$, $p = 0.001$) (Graph 2) and 57.7% of the variation in SPL was explained by air pressure, indicating a correlation with the 0.69 coefficient induced by an increase in subglottal air pressure.

Discussion

As it is important for singers to increase voice power, it is also important for them to increase voice intensity. Plant et al. [1] and Holmberg et al. [4] state that combination of the laryngeal aerodynamic properties of SPL value and the vibration properties of plica vocalis determines the characteristics of voice sound production. The formation of glottal vibrations under the plica vocalis at laryngeal

level takes place under the control of subglottic pressure. Both vocal intensity and pitch are thought to be influenced by subglottic air pressure. The effective use of subglottic pressure to achieve a higher level of vocal intensity is taught in voice training. Therefore, it is important for both singers and non-singers to determine the level of vocal intensity and how to control it. In the present study, the values of subglottic air pressure, subglottic airflow and Sound Pressure Level (SPL) in participants with and without voice training were measured and recorded simultaneously during the vocalizations given at high intensity, using the Aero view Pro Phonatory Aerodynamics System through intraoral way. In addition, the vocal intensity was determined using the Sound Level Meter 2240 B&K method, and the SPL results obtained through two methods were compared. The mean of SPL values measured at high intensity was found as 105.0 dB using the Aero view Pro Phonatory Aerodynamics System and 106.5 dB using the B&K 2240, which were close to each other. In other studies, normal vocal intensity levels were determined [4,5,6]. However, in our study, high levels of vocal intensity were determined using two methods, and the vascular dynamism occurring due to glottal flow and pressure was tried to be revealed in participants with and without voice training. Akerlund et al. [5] examined the relationship between SPL and FO in individuals with classical vocal training, using the Bruel & Kjaer 2033; and obtained high SPL values, which are similar to those found in the present study. In this study, a logarithmic relationship was found between subglottic air pressure and SPL. In addition, the mean correlation between subglottic pressure and SPL was found to be 0.85 [SD, 0.203] [$Y \text{ SPL} = 0.85 * X \text{ Air pressure}$].

Bjorkland et al. [6] found a logarithmic relationship between subglottic air pressure and SPL in non-singer normal subjects. In addition, they also found the mean correlation between subglottic pressure and SPL as 0.83, which is very close to the correlation found in the present study. Holmberg et al. [4] reported higher airflow in males than in females under normal and high voice frequencies. Sjogrens et al. [7] reported that airflow did not vary in both singers and non-singers, indicating high rates of airflow in non-singers and low rates of air flow in singers, which is also similar to the present study results. Similar to the present study results, they observed lower subglottic pressure and SPL values in individuals without voice training. The present study found no statistically significant difference between participants' airflow, air pressure and SPL mean values with respect to gender. Björkland et al. [6] examined the relationship between subglottic pressure and SPL in healthy individuals who had not received vocal training, and found that the mean SPL of female participants were significantly lower than the mean of male participants [$P < 0.04$]. As a result, vocal training was observed to affect vocal intensity. An easy determination of SPL values would be useful in evaluating voice problems for clinical practices as a fast, simple and inexpensive tool. It will also contribute to create normative values in healthy non-singers and singers. Although our study results are similar to those of other studies, the present found a significant difference between participants with respect to changes in vocal intensity. Because the participants with opera voice training have experienced wide range of changes in high vocal intensity.

Conclusion

The research data verify that the increase in subglottic pressure is the determinant of the increase in vocal intensity. The subglottic airflow in singers shows a constant continuity and seems to be

ineffective in changing air pressure and vocal intensity. Singing teaches aerodynamically effective use of laryngeal structures. Compared to non singers, opera and voice professionals have aerodynamic differences in their use of respiration capacities during singing. They were observed to have a tendency to generate high subglottic air pressure and high vocal intensity with a minimum airflow at a constant rate. In addition, during their trainings, singers learn how to control vocal structures more capacity and effectively by using intrinsic and extrinsic muscles of the larynx, hyoid-larynx complex, vibration patterns of plica vocalis and positional changes of supraglottic region.

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