

Physiologic Laryngeal Changes in Operatic Singers After Different Vocal Loading Tasks

Opera Sanatçılarının Farklı Vokal Kayıt Testleri Sonrası Larinkslerindeki Fizyolojik Değişiklikler

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ABSTRACT Objective: This study aimed to measure changes in vocal folds color throughout two solo performance tasks. **Material and Methods:** For this purpose, 30 healthy trained classical singers aged between 27 and 35 years (15 males and 15 females) were the subjects of the study. Two types of vocal loading task were employed: (1) 20 minutes of singing and (2) 60 minutes of singing. In the first type the investigations were performed twice: before singing and 15 minutes later. In the second type the investigations were made three times: in the morning before singing, after 15 minutes of vocal rest and after 12 hours of vocal rest. The investigation included laryngoscopy, laryngostroboscopy and acoustic test. **Results:** It was revealed that after the first type of vocal loading hyperemia of the vocal folds did not appear in any of singers. This appeared in 15 minutes of vocal rest after the second type of loading and was prolonged not less than 12 hours in 25 singers. Laryngostroboscopy and acoustic test did not reveal pathology in these participants. Five subjects had no color changes in second type of vocal loading. **Conclusion:** Hyperemia of the vocal folds was revealed in 83.3% of participants after 60 minutes of singing and prolonged not less than 12 hours. Hyperemia accomplished neither vocal discomfort nor objective deteriorations of vocal quality and could be estimated as physiologic laryngeal condition. In the remaining 16.7% of performers hyperemia was not revealed. This could be regarded as more high level of their individual vocal endurance, or as individual peculiarity of their larynx.

Key Words: Vocal cords; laryngeal diseases

ÖZET Amaç: Bu çalışmanın amacı 2 solo performans testleri sırasında ses tellerindeki renk değişikliklerini incelemektir. **Gereç ve Yöntemler:** Bu amaçla 27-35 yaşlar arasındaki 30 sağlıklı, yetişmiş, eğitilmiş opera sanatçısı (15 erkek ve 15 kadın) çalışmaya dahil edildi. Ses kayıt testleri 1) 20 dakika şarkı söyleme ve 2) 60 dakika şarkı söyleme idi. Birinci tip testte inceleme hem şarkı söyleme öncesi hem de 15 dakika sonrası yapıldı. İkinci tip testte inceleme 3 kez yapıldı: şarkı söyleme öncesi sabah, 15 dakika ses tellerinin dinlendirilmesi sonrası ve ses tellerinin dinlendirilmesinin 12 saat sonrasında. Bu incelemeler: laringoskopi, laringostroboskopi, akustik test idi. **Bulgular:** Sanatçıların hiçbirinde, 1. tip test sonrası ses tellerinde hiperemi görülmedi. 2. tip testin sonrasında 15 dakikalık dinlenme sonunda 25 sanatçıda bu görüldü, fakat 12 saatten uzun sürmedi. Katılımcılarda laringostroboskopi ve akustik test ile hiçbir patoloji saptanmadı. Katılımcıların %5'inde 2. test sonrası hiçbir renk değişikliği yoktu. **Sonuç:** Katılımcıların %83,3'ünde şarkı söyleme sonrası 60. dakikada, ses tellerinde hiperemi saptandı ve 12 saatten daha fazla sürdü. Hiperemi ses tellerinde rahatsızlık duygusu oluşturmadığı gibi sesin kalitesinde bozulmada yapmadı, o nedenle fizyolojik bir durum olarak kabul edilebilir. Kalan %16,7 katılımcıda hiperemi görülmedi. Buna göre ses tellerinin bireysel dayanıklılığından ve larinksin bireysel yapı özelliklerinden söz etmek mümkündür.

Anahtar Kelimeler: Ses telleri; larinks hastalıkları

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It's a routine part of classical singer's life in Russia to be periodically examined by a phoniatician. Healthy singers come to see the phoniatician, who works at State Opera and Ballet Theatre and Music College, principally for control examination. Hyperemia of the vocal folds revealed frequently in many singers, because they prefer to sing every other day to keep their good professional form. It's considered that if this hyperemia disappears during 2-3 hours of vocal rest this could be regarded as physiologic condition of the larynx.^{1,2} Meantime, our experience indicates, that hyperemia may exists much longer in many singers. Some phoniaticians and singing teachers consider, that prolonged hyperemia of vocal folds is an indication of inappropriate use of the voice, i.e. incorrect singing.

Laryngoscopy plays a central part during examination of professional performers. But for estimation vibratory properties of the vocal folds laryngostroboscopy must be done.³⁻⁵ Acoustic voice analysis indicates the status of the phonatory system and can be useful in the evaluation of singing voice.⁶⁻⁸ The present study was carried out in order to test: (1) what vocal loading task could result to hyperemia of the vocal folds; (2) how long this hyperemia persists; and (3) how this influences to singing voice.

MATERIAL AND METHODS

SUBJECTS

Thirty healthy classical singers aged between 27 and 35 years were the subjects of this study. All participants were soloists of Krasnoyarsk State Opera and Ballet Theatre: 15 males (5 tenors, 5 baritones, 5 basses) and 15 females (5 sopranos, 7 mezzo-sopranos). The subjects were all nonsmokers. None of them suffered from acid reflux or inhalation of airborne irritants, both of which can lead to inflammation of the vocal folds. None of singers had vocal trauma previously. Informed consent and ethical approval were obtained for each subject of the investigation.

Two types of vocal loading (familiar operatic arias of professional level vocal difficulty) were em-

ployed in this research: (1) 20 minutes of singing and (2) 60 minutes of singing. These tasks included the same repertoire. During 60 minutes of singing participants repeated a 20 minute singing session three times. Vocal loading types were performed in different days. In females investigations were carry out outside of menses. In the first type of loading the investigations were made twice: before singing and 15 minutes later. In the second type of loading the investigations were made three times: in the morning before singing, after 15 minutes of vocal rest and after 12 hours of vocal rest.

MEASUREMENTS

The investigation, including laryngoscopy, laryngostroboscopy and acoustic test, was made by the same clinician in the Voice Research Laboratory of the State Opera and Ballet Theatre. Laryngoscopy-cal data were obtained using mirror laryngoscopy. For rigid endoscopy of larynx the following ELEPS instruments (Russia) were used: endoscope type PH402718C 70°, digital endoscopic video camera EVC-001 S-VHS and color video monitor W 3502 S-VHS 37 cm. Laryngostroboscopy was carry out by means of laryngostroboscope ELS-03 (Russia) using soft phonation (around 65 dB) in chest register. Laryngostroboscopy and acoustical test were used only in singers, in which hyperemia of vocal folds appeared after vocal loading. Acoustical test was performed in all subjects before singing for obtaining control data.

Acoustic analyses of voice were carried out with the computer program Praat.⁹ Following data were gathered: speaking fundamental frequency (SF0), jitter (F0 perturbations in the period time of vibrations), shimmer (F0 perturbation in the amplitude of the vibrations) and signal to noise ratio (S/N) represented the amount of noise in the voice. Jitter (local) was calculated as the ratio of the mean absolute difference in consecutive periods to the mean period. Multidimensional Voice Program (MDVP) calls this parameter *Jitt*). Shimmer (local) was calculated as the ratio of the mean absolute difference in the amplitudes of consecutive periods to the mean amplitude (MDVP calls this parameter *Shim*). Laptop Hewlett-Packard 630, Pentium

B960, 2, 2 GHz was used for both data acquisition and analysis. For estimation SF0 the subjects read the same Russian text at comfortable frequency and intensity level during about 25 seconds. For estimation jitter, shimmer and S/N ratio singers were asked to produce the vowel [a:] during 4-5 seconds in chest register using standard frequency (128 Hz for males and 220 Hz for females) and intensity level around of 75 dB. All voice samples were recorded in a well-damped room using a measuring microphone Gembird EMIC-111. The mouth-to-microphone distance was 30 cm as recommended by Baken and Orlikoff.⁷ Acoustic results were statistically analyzed using Student's *t*-test and constituted Table 1. Statistical significance was defined using *p* values less than 0.05.

RESULTS

Laryngoscopy before singing revealed light gray in color vocal folds in all subjects. Laryngostroboscopy at this time revealed symmetrical, periodic vocal fold vibrations with sufficient vibratory closure. The vibratory amplitudes and the mucosal waves were normal in size. Acoustic test revealed the following findings in males: SF0 124 Hz (SD 13.4), jitter 0.36% (SD 0.27), shimmer 1.08 dB (SD 0.36), S/N 14.1 (SD 2.42). In females: SF0 227 Hz (SD 29.5), jitter 0.31 % (SD 0.23), shimmer 0.79 dB (SD 0.31), S/N 15.9 (SD 2.31).

After the first type of vocal loading, hyperemia of the vocal folds did not appear in any singer. Hyperemia appeared in 15 minutes of vocal rest after

the second type of loading in 25 subjects (12 males and 13 females), that consisted 83.3% of all singers. Hyperemia did not coincide with swelling of the focal folds and clinging viscous sputum on their free edges. None of singers complained of vocal problems. Laryngostroboscopy revealed symmetrical, periodic vocal fold vibrations with sufficient vibratory closure. The vibratory amplitudes and the mucosal waves were normal in size. Acoustic test was performed and revealed the following magnitudes in males: SF0 127 Hz (SD 12.8), jitter 0.26% (SD 0.22), shimmer 0.88 dB (SD 0.36), S/N 16.1 (SD 2.42). In females: SF0 222 Hz (SD 29.0), jitter 0.21% (SD 0.18), shimmer 0.59 dB (SD 0.24), S/N 18.8 (SD 2.26).

After 12 hours of vocal rest hyperemia did not disappear in any of subjects. Singers had no voice complains. Stroboscopy confirmed normal vibrations of vocal folds. Acoustic test findings were obtained and revealed in males: SF0 120 Hz (SD 12.4), jitter 0.36 % (SD 0.29), shimmer 1.02 dB (SD 0.36), S/N 14.8 (SD 2.42). In females: SF0 230 Hz (SD 28.5), jitter 0.28 % (SD 0.26), shimmer 0.67dB (SD 0.28), S/N 16.9 (SD 2.34). The comparison results of the acoustic test can be seen in Table 2 and Table 3.

DISCUSSION

Reliable estimation of the vocal folds color in classical singers is very important. Investigation of the larynx by means of rigid or flexible endoscopy sometimes cannot obtain natural color of the vocal folds.¹⁰ Thus mirror laryngoscopy in singers re-

TABLE 1: Mean values of acoustic voice test in singers after 60 minutes of singing.

Subjects	n	SF0 (Hz)	Jitter (%)	Shimmer (dB)	S/N (dB)
Males	15				
Before singing	15	124 (SD 13.4)	0.36 (SD 0.27)	1.08 (SD 0.36)	14.1 (SD 2.42)
After 15 min of vocal rest	12	127 (SD 12.8)	0.26 (SD 0.22)	0.88 (SD 0.36)	16.1 (SD 2.42)
After 12 hours of vocal rest	12	120 (SD 12.4)	0.36 (SD 0.29)	1.02 (SD 0.36)	14.8 (SD 2.42)
Females	15				
Before singing	15	227 (SD 29.5)	0,31 (SD 0.23)	0.79 (SD 0.31)	15.9 (SD 2.31)
After 15 min of vocal rest	13	222 (SD 29.0)	0.21 (SD 0.18)	0.59 (SD 0.24)	18.8 (SD 2.26)
After 12 hours of vocal rest	13	230 (SD 28.5)	0.28 (SD 0.26)	0.67 (SD 0.28)	16.9 (SD 2.34)

n: Number of participants; SF0: Speaking fundamental frequency; S/N: Signal-to-noise ratio; SD: Standard deviation.

TABLE 2: p values in males obtained by comparison of acoustic test findings after 15 minutes and after 12 hours of vocal rest.

Investigation	After 15 min				After 12 hours			
	SF0	Jitter	Shimmer	S/N	SF0	Jitter	Shimmer	S/N
Before singing								
SF0	0.561				0.433			
Jitter		0.310				1.000		
Shimmer			0.164				0.671	
S/N				0.043				0.462
After 15 min								
SF0					0.165			
Jitter						0.352		
Shimmer							0.351	
S/N								0.202

TABLE 3: p values in females obtained by comparison of acoustic test findings after 15 minutes and after 12 hours of vocal rest.

Investigation	After 15 min				After 12 hours			
	SF0	Jitter	Shimmer	S/N	SF0	Jitter	Shimmer	S/N
Before singing								
SF0	0.663				0.799			
Jitter		0.256				0.763		
Shimmer			0.078				0.397	
S/N				0.003				0.304
After 15 min								
SF0					0.503			
Jitter						0.451		
Shimmer							0.460	
S/N								0.055

quires. In most healthy singers the vocal folds appear light grey in color. In males after strong singing prolonged hyperemia of the vocal folds coincides with edema of the vocal folds and clinging viscous sputum their free edges. This could be regarded as acute professional laryngitis.¹¹ In females after heavy voice use hyperemia of the vocal folds frequently coincides with bilateral, symmetrical soft swellings at the junction of the anterior and middle thirds of the vocal folds. Gray et al. have suggested that repetitive swelling at this place can lead to structural changes in the basement membrane zone of the vocal folds and may predisposed to development of vocal fold nodules.¹²

In the light of findings of our investigation, short-term vocal loading (20 minutes) did not result to hyperemia of the vocal folds in all participants. Long-term singing (60 minutes), on the contrary, leads to hyperemia of folds in the majority of singers. Meantime, none of them complained of vocal problems. Laryngostroboscopy in these subjects did not reveal changes of vocal folds vibration. Anything that increases the effective mass of the vocal fold, including the vocal fold swelling, will tend to lower the SF0.⁷ In our study hyperemia of the vocal folds coincided with edema of the vocal folds in none of singers. Therefore differences of the SF0 values in subjects before singing, after 15

minutes and 60 minutes of vocal rest were non-significant respectively (Table 2 and Table 3). Increased fundamental frequency perturbations (jitter and shimmer) are associated with the perception of vocal hoarseness.⁷ We did not reveal this tendency in our study. Differences of jitter and shimmer values before singing, after 15 minutes and 60 minutes of vocal rest in both males and females were non-significant respectively (Table 2 and Table 3).

The S/N ratio is the objective index of the degree of vocal hoarseness. Increased ratio indicates a reduction in the vocal noise and vice versa.¹³ This ratio was significantly increased in all 25 subjects in 15 minutes after vocal loading and decreased significantly after 12 hours of vocal rest (Table 1 and Table 2). This could be explained by the effect of warm-up of the vocal folds, which appeared in 15 minutes after vocal loading and disappeared in 12 hours of vocal rest.

Five participants, 3 males and 2 females (16.7%), after 60 minutes of singing had no changes in

color of the vocal folds. These singers also did not complain of vocal disturbances. On the one hand, this indicated more high level of individual vocal endurance, but on the other hand, could be regarded as individual peculiarity of their larynx.

CONCLUSION

Hyperemia of the vocal folds was revealed in 83.3% of participants after 60 minutes of singing and prolonged not less than 12 hours. Hyperemia accomplished neither vocal discomfort nor objective deteriorations of vocal quality and could be estimated as physiologic laryngeal condition. In the remaining 16.7% of performers hyperemia was not revealed. This could be regarded as more high level of their individual vocal endurance, or as individual peculiarity of their larynx.

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