Effect of Chant Training on the Morphology of the Lateral Thyrohyoid Ligament: A Biometric and Acoustic Assessment

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Summary: Objective. The purpose of this study was to determine the effects of chant training both on the morphologic structure of the lateral thyrohyoid ligament (LTL) and on the acoustic characteristics of the voice.
Methods. Three groups of people participated in the study. Group I was new to chant training, group II had completed or was still continuing chant training, and group III, the control group, did not have any chant training. For all participants, laryngeal cervical magnetic resonance imaging was performed to measure the right and the left LTLs. Additionally, vocal acoustic analyses were performed and compared with the anatomic morphometric measurements. Appropriate statistical assessments were performed to evaluate the measurements.
Results. The length of the LTL was greater in men, and this finding supports the gender-specific differences in laryngeal structures. Anatomic differences between groups showed that 8 months of training was not sufficient to trigger morphologic changes. The left and right LTLs were asymmetric, but this finding was not statistically significant.
Conclusions. Analyses revealed that vocal training causes morphologic changes in anatomic structures, which affect vocal quality.
Key Words: Right lateral thyrohyoid ligament−Left lateral thyrohyoid ligament−Metric analysis−Acoustic analysis−MRI.

INTRODUCTION

Voice plays a key role in everyday communication and social interactions. Singing is one of the most important dimensions of musical arts. Having just a "good voice" is not adequate for singing. Having both a healthy body and larynx is necessary for a high-quality voice. Many laryngeal structures change with voice training. Ligaments and membranes, which are the intrinsic elements of the larynx, contribute to laryngeal movements to produce voice. The thyrohyoid membrane, a wide fibroelastic lamina that resides between the thyroid cartilage and the hyoid bone, connects the larynx to the hyoid bone. This membrane allows the hyoid bone and the thyroid cartilage to move together during vocal production and swallowing. Singing changes the morphology of laryngeal ligaments and other anatomic laryngeal structures. The thyrohyoid membrane takes its banded shape by thickening at both sides of the larynx. This band reaches from the superior horns of the thyroid cartilage to the greater horns of the hyoid bone. This portion is called the lateral thyrohyoid ligament (LTL).

The morphometric changes in the laryngeal anatomic structures involved in speaking and singing are particularly important for the laryngologist to evaluate. The laryngologist will diagnose any phonatory diseases, determine the roles of these structures in phonation control, and plan surgery accordingly.[1,2] Computerized tomography and magnetic resonance imaging (MRI) are widely used for the assessment of the larynx morphometry and in the follow-up of phonatory diseases.[3] Metric analysis of these structures is preferred because stacking various morphologic forms, which are determined by morphometric measurements in imaging studies, over each other eliminates the need for a common reference plane. Metric analysis aims to define the anatomic structures quantitatively.[4] In the present study, we evaluated the metric analysis of the LTL using MRI and also obtained acoustic measures of the voice to determine the changes that voice training may have on laryngeal anatomic structures.

METHODS

The present study included 16 men and 16 women between 17 and 35 years of age. Participants who previously took or were still taking vocal training at the time of the study were recruited from a group of opera and chant students. Those participants without voice training were students from the medical school. Group I was new to chant training, Group II had completed or was still continuing chant training, and Group III, the control group, did not have any chant training. Female and male distributions among the study groups were six of six in Group I, five of five in Group II, and five of five in the control group. The participants were matched according to gender, weight, and education level. The mean height of the women and men were 164.4 + 6.1 cm and 175.6 + 4.9 cm in the control group, 167.7 + 7.0 cm and 179.8 + 3.8 cm in Group I, and 164.8 ± 3.9 cm and 178.2 ± 5.1 cm in Group II, respectively. After the participants were informed about the study, laryngeal examinations were done in the Ear, Nose and Throat Department of the Faculty of Medicine of Cukurova University. Participants without any pathology regarding voice diseases were included in the study. One participant with a nodule on the left plica vocalis was referred for surgery and was excluded from the study.

Laryngeal cervical MRI examinations of 16 participants were conducted at the Private Cukurova Guven Surgery Medical Center. The participants were instructed

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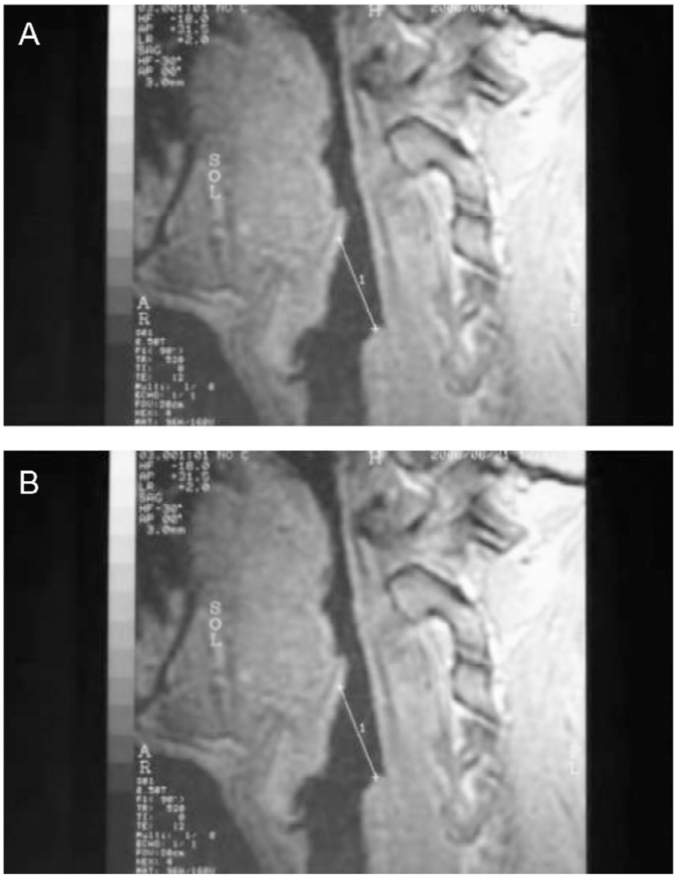

FIGURE 1. MRI of a male participant in the control group shows (**A**) the measurement of the right lateral thyrohyoid ligament and (**B**) the measurement of the left lateral thyrohyoid ligament.

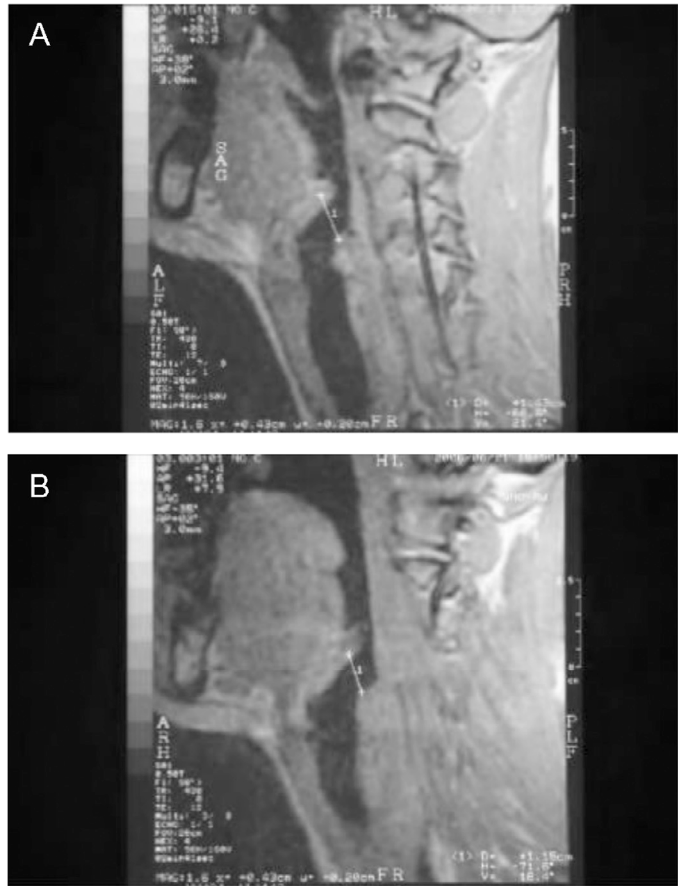

FIGURE 2. MRI of a female participant in the control group shows (**A**) the measurement of the right lateral thyrohyoid ligament and (**B**) the measurement of the left lateral thyrohyoid ligament.

to take a normal breath during the MRI procedure. The study was approved by the Ethical Commission for Clinical Research in the Medical Faculty of Cukurova University. The length of the LTL, which resides between the hyoid bone and the superior horn of the thyroid cartilage, was measured morphometrically between end points on the MRI by using *Adobe Photoshop CS2* (Version 9.0) (Adobe, San Jose, CA) (Figures 1−6). Then, jitter, shimmer, and fundamental frequencies of the voices of the participants were measured using *Dr. Speech 6.2* ((Tiger DRS, Inc., Seattle, WA) voice analysis software at the Ear-Nose-Throat Department of Cukurova University Faculty of Medicine, Balcali Hospital. For the sample recordings, the participants produced an "a" vocalization for 5 seconds in a comfortable pitch. These procedures were performed in each group. The measurements were repeated after 8 months in each group.

Statistical analysis

Statistical comparisons between gender groups were performed with the Mann-Whitney *U* test, and comparisons between and within the first and the last measurements were performed with the Wilcoxon test by using the *SPSS Statistical Software for Windows* (Version 13.0) (IBM, Armonk, NY).

RESULTS

The mean ages of the women and the men were 20.4 ± 1.1 years and 21.8 ± 2.9 years in the control group, 18.7 ± 1.8 years and 19.8 ± 1 years in Group I, and 21.0 ± 3.5 years and 30.0 ± 6.9 years in Group II, respectively. Four men in the control group and three males and one female in Group II were smokers. As the number of the participants was low, smoking was not considered as an exclusion criterion (Table 1). Lengths of the LTLs were obtained from the cervical MRIs and measured biometrically on the first and the final images (Table 2). Results were compared within and between groups using the first and the last images (Tables 3−5). Both biometric measurements and acoustic vocal measurements between the initial and the final assessments within the control group did not reveal a significant difference. Because the participants in the control group had no voice training, we hypothesized that these similarities reflect the laryngeal anatomy when no vocal training has taken place.

Comparisons of the results between the control group and Group I revealed a gender effect. The initial and the final measurements of the right LTL ($P = 0.004$) and the initial measurement of the left LTL were found to be shorter in the male participants in Group I than in the male participants in the control group ($P < 0.05$) (Table 3). Comparison of the

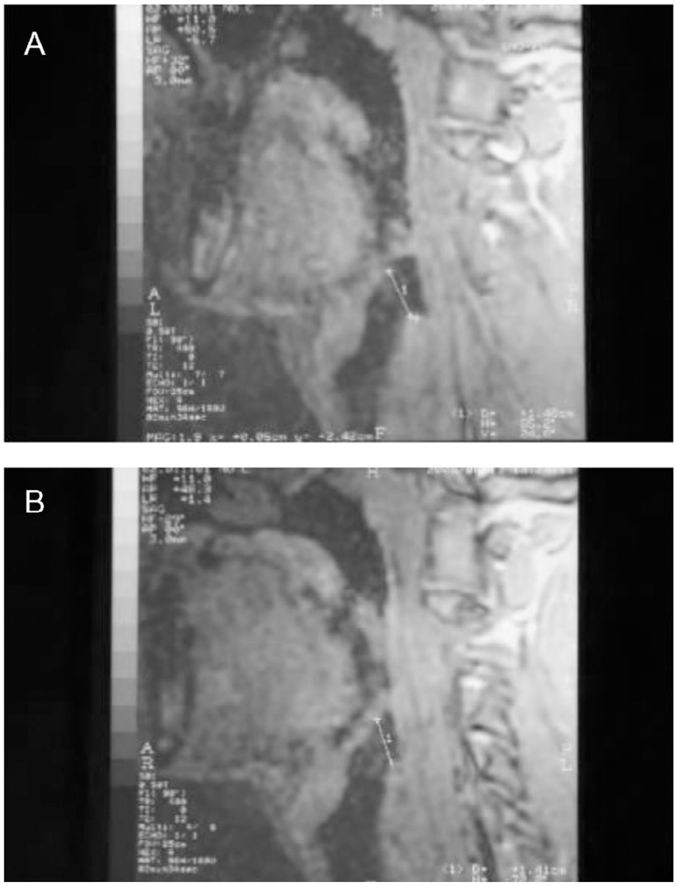

FIGURE 3. MRI of a male participant in Group I shows (**A**) the measurement of the right lateral thyrohyoid ligament and (**B**) the measurement of the left lateral thyrohyoid ligament.

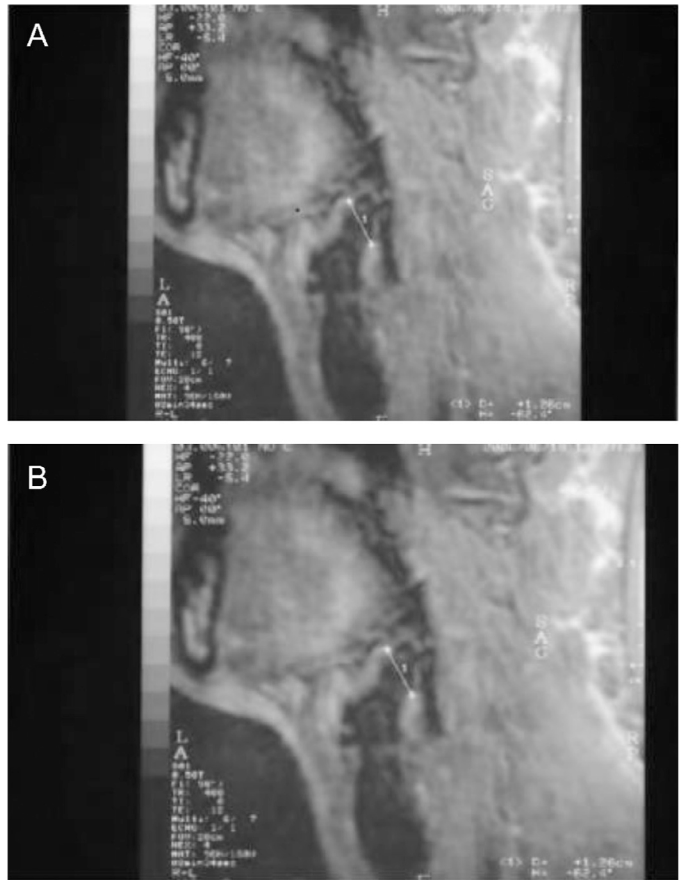

FIGURE 4. MRI of a female participant in Group I shows (**A**) the measurement of the right lateral thyrohyoid ligament and (**B**) the measurement of the left lateral thyrohyoid ligament.

final measurement of the left LTL was not statistically significantly different.

The comparisons of female participants in the control group and in Group I revealed that initial and final jitter measurements were significantly lower in Group I than in the control group ($P < 0.05$). The within-group comparisons in these groups of female participants also showed that fundamental frequencies were significantly increased in the final measurements compared with the initial assessments ($P = 0.028$) (Tables 3–5). When it was considered that participants in Group I were at the beginning of their voice training, we concluded that this indicated the onset of changes in ligament size and vocal production. Nevertheless, our results also suggested that 8 months of vocal training was not sufficient for operachant training. The first measurement averages of the right LTL (mm) in the women in the control group and in Group I were statistically similar ($P = 0.931$). The comparisons between Groups I and II revealed that the lengths of the left LTL were significantly decreased in the final assessments of the female participants in Group II ($P < 0.05$) (Table 3). In addition, the female participants in Group II had significantly decreased fundamental frequencies in their final assessments. ($P < 0.05$) (Table 3). Because women in this group were taking voice training for a longer period, we hypothesize that the differences were a result of the voice training. The comparisons between the initial and the final assessments of the male participants in Group II revealed no statistically significant difference ($P > 0.05$). Although men and women were taking the same training, we hypothesize that the lack of difference in the initial and the final measurements of the right and the left LTLs, and the acoustic parameters (including fundamental frequency, jitter, and shimmer) were due to the 60% smoking rate in the male participants in this group. Smoking negatively affects the voice training of these participants.

DISCUSSION

Laryngologists rely on accurate knowledge of the laryngeal anatomy for diagnoses and treatments of pathologies associated with voice disorders.[1] It is particularly important for the laryngologist to be aware of and to take into account gender-specific differences and morphologic characteristics associated with anatomic changes in relation to voice training.[5] Unlike individuals who have not received vocal training, singers learn to coordinate many physiological processes by making physiological adaptations between the articulatory and laryngeal structures during chant training. Singers learn to stabilize vocal output by using their extrinsic laryngeal muscles. They use the intrinsic laryngeal muscles for adduction, abduction, and tension of the vocal chords.[1] The larynx is in a lower

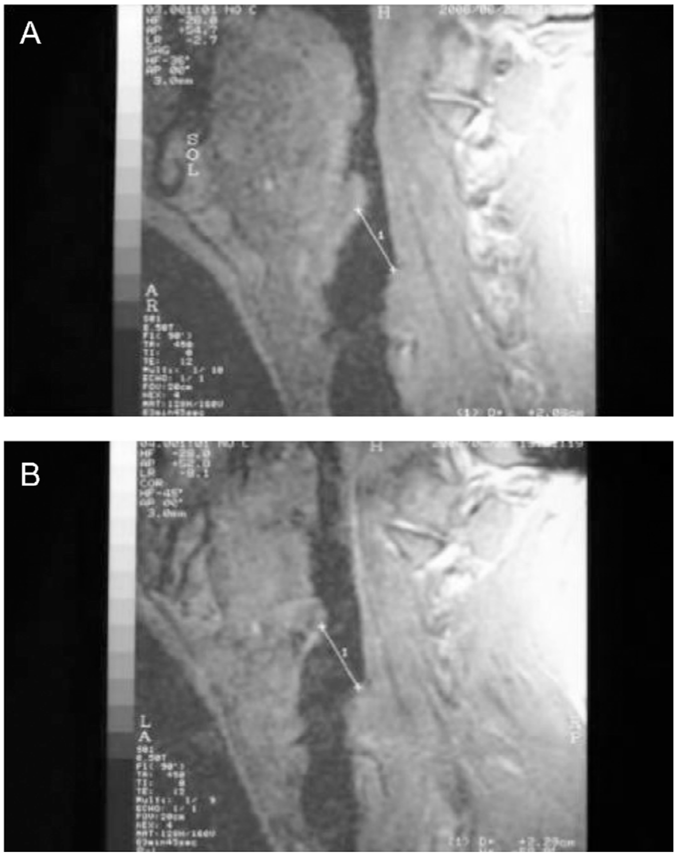

FIGURE 5. MRI of a male participant in Group II shows (**A**) the measurement of the right lateral thyrohyoid ligament and (**B**) the measurement of the left lateral thyrohyoid ligament.

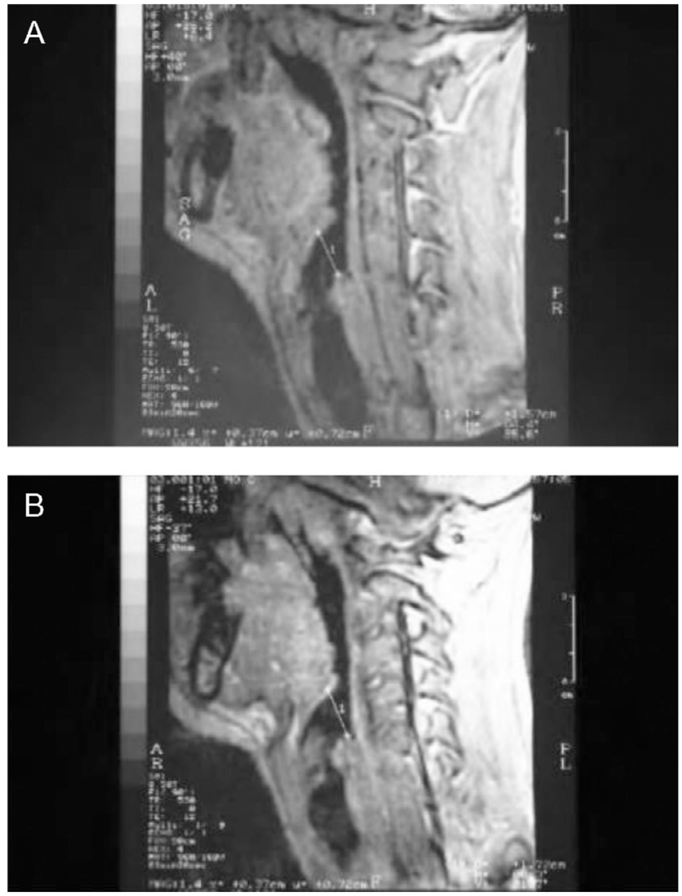

FIGURE 6. MRI of a female participant in Group II shows (**A**) the measurement of the right lateral thyrohyoid ligament and (**B**) the measurement of the left lateral thyrohyoid ligament.

position during singing. Lowering the position of the larynx, especially for classical male singers, is considered a typical movement.[6] Stepp et al[7] reported that nonsingers tended to ascend their larynx, but singers tended to keep their larynx below the resting height.

Ligaments and cartilages are also modified as much as the muscles during vocal adjustments. Anatomic structures behave as a separate small anatomic complex distinct from the muscles.[8] When the thyroid cartilage begins its descent, the thyrohyoid membrane descends to a new position as well. Because the thyroid cartilage moves together with the hyoid bone, it stretches the thyrohyoid membrane. Therefore, compliance-related changes in these ligaments are expected with regard to their usage.[1] Sonninen et al[9] evaluated the positional changes in the laryngeal structures according to the tone, register, and song mode and reported that the hyoid bone also adjusts to make vertical and sagittal directional changes when the pitch increases or decreases. According to Sonninen et al,[9] the hyoid bone moves in a posterior-inferior direction by descending, especially during the production of certain frequencies. The hyoid-thyroid distance was reportedly decreased during high pitches in all singing modes. The head and neck also change their positions during vocal productions and so does the hyoid bone. The hyoid bone takes its position according to the movements of the mandible and the vocal functions of the larynx. Age and gender also contribute to the influence of the hyoid bone and other laryngeal structures. Sprinzl et al[1] reported that there are certain differences between the dimensions of the cartilages and ligaments of larynxes of men and women. Sprinzl et al reported the length of the LTL of men and women as 18.1 ± 1.6 mm and 14.4 ± 1.2 mm, respectively. Loth et al[4] reported the distances between the greater horn of the hyoid and the superior horn of the thyroid cartilage in 104 computed tomography scans of individuals between 19 and 62 years of age as 23.83 and 24.64 mm in women and 25.37 and 23.98 mm in men for the left and the right lateral thyrohyoid distances, respectively. Loth et al[4] obtained these measurements between coordinates of the greater horn of the hyoid and the superior horn of the thyroid cartilage from computed tomography scans of adults using the Procrustes superimposition and the principal component analysis methods. These subjects had no prior voice training. Findings in our study included initial and final measurements of 12.0 ± 1.8 mm and 11.1 ± 1.8 mm for the right LTL and 12.3 ± 1.8 mm and 11.6 ± 1.8 mm for the left LTL in women. These values were 22.1 ± 2.0 mm and 20.2 ± 4.0 mm for the right LTL and 21.9 ± 2.6 mm and 21.2 ± 4.1 mm for the left LTL in men.

Similar to the morphometric measurements of Sprinzl et al,[1] we found that the LTLs of the men were longer than those of the women. Loth et al[4] have reported the asymmetry in the

TABLE 1.
Smoking Rates and Percentages in the Groups

Variables		Control Group		Group I		Group II	
		Count	%	Count	%	Count	%
Smoking	None	6	60.0	12	100,0	6	60.0
	Existing	4	40.0	0	0,0	4	40.0

TABLE 2.
Initial and Final Measurements of the Right and the Left Thyrohyoid Ligaments in the Study Groups

		Control Group		Group I		Group II	
		Female	Male	Female	Male	Female	Male
		(n = 5)	(n = 5)	(n = 6)	(n = 5)	(n = 5)	(n = 6)
Variables		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Right lateral thyrohyoid ligament (mm)	Initial	12.2 ± 1.8	21.6 ± 2.3	12.0 ± 0.6	12.2 ± 1.8	21.6 ± 2.3	12.0 ± 0.6
	Final	12.3 ± 1.8	21.9 ± 2.6	12.4 ± 0.7	12.3 ± 1.8	21.9 ± 2.6	12.4 ± 0.7
Left lateral thyrohyoid ligament (mm)	Initial	11.4 ± 1.8	20.4 ± 3.8	13.7 ± 2.9	11.4 ± 1.8	20.4 ± 3.8	13.7 ± 2.9
	Final	11.6 ± 1.8	21.2 ± 4.1	14.8 ± 3.9	11.6 ± 1.8	21.2 ± 4.1	14.8 ± 3.9

Abbreviation: SD, standard deviation.

cartilage structures of the adult larynx and concluded that the left thyroid and cricoid lamina distances were higher. In our study, we have only observed an asymmetry in the left LTLs of the men in Group II and the women in Group I, but this finding was not statistically significant.

Hollien[10] suggested that excellent singing can be achieved by either talent or training. Sulter et al[11] reported that there were findings reflecting some native or acquired laryngeal functions in individuals who took training compared with individuals without any training. Besides being chosen due to talent, students in the conservatory advance their voice quality by training. Mendes et al[12] followed up students taking voice training for four semesters and reported that the perturbation measurements, including jitter, shimmer, and harmonic-to-noise ratio, decreased with respect to increased duration of training. Lundy et al[13] have stated that a decreased jitter, shimmer, and noise harmonic rates might be indicators of advanced voice quality in the chant. Our study revealed that chant training might have significant effects on voice quality. Our study revealed findings suggesting that increased duration of chant training had significant effects on voice quality. Specifically, the effects of training

TABLE 3.
Comparison of Right and Left Thyrohyoid Ligament Lengths and Acoustic Analysis Values in Independent Groups

		Control Group versus Group I		Control Group versus Group II		Group I versus Group II	
		Female	Male	Female	Male	Female	Male
		(n = 5)	(n = 5)	(n = 6)	(n = 5)	(n = 5)	(n = 6)
Variables		*P* Value	*P* Value	*P* Value	*P* Value	*P* Value	*P* Value
Right lateral thyrohyoid ligament (mm)	Initial	0.931	0.004*	0.222	0.548	0.126	0.537
	Final	0.126	0.009*	0.310	0.421	0.052	0.329
Left lateral thyrohyoid ligament (mm)	Initial	0.931	0.030*	0.222	0.421	0.126	0.662
	Final	0.082	0.082	0.310	0.310	0,044*	0.662
Jitter (%)	Initial	0.030 *	0.537	0.008*	1.000	0.429	0.429
	Final	0.017*	0.662	0.032*	1.000	0.429	0.931
Shimmer (%)	Initial	0.082	0.792	0.016*	0.310	0.126	0.247
	Final	0.126	0.537	0.032*	0.841	0.792	0.931
Fundamental frequency (Hz)	Initial	1.000	0.931	0.690	0.548	0.931	0.429
	Final	0.931	0.537	0.310	1.000	0,045*	0.792

* Mann-Whitney *U* test $P < 0.05$.

TABLE 4.
Initial and Final Measurement Averages of Acoustic Analysis Values According to Groups

		Control Group		Group I		Group II	
		Female	Male	Female	Male	Female	Male
		(n = 5)	(n = 5)	(n = 6)	(n = 5)	(n = 5)	(n = 6)
Variables		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Jitter (%)	Initial	0.24 ± 0.03	0.22 ± 0.10	0.16 ± 0.05	0.19 ± 0.09	0.13 ± 0.03	0.23 ± 0.08
	Final	0.21 ± 0.04	0.18 ± 0.02	0.15 ± 0.04	0.19 ± 0.05	0.15 ± 0.02	0.19 ± 0.06
Shimmer (%)	Initial	2.45 ± 0.69	1.57 ± 0.43	1.80 ± 0.54	1.42 ± 0.51	1.31 ± 0.43	1.82 ± 0.30
	Final	1.80 ± 0.39	1.30 ± 0.50	1.37 ± 0.67	1.54 ± 0.38	1.07 ± 0.42	1.72 ± 1.01
Fundamental	Initial	242.40 ± 15.61	149.93 ± 44.20	242.44 ± 19.55	135.53 ± 20.46	245.00 ± 9.28	126.54 ± 14.68
frequency (Hz)	Final	262.20 ± 35.42	133.01 ± 23.37	268.40 ± 14.19	124.57 ± 16.26	243.36 ± 21.23	130.27 ± 17.37

Abbreviation: SD, standard deviation.

TABLE 5.
Comparison of Left and Right Thyrohyoid Ligament Lengths and Acoustic Analysis Values Within Gender Groups (Initial and Final)

		Group I		Group II		Control Group	
		Female	Male	Female	Male	Female	Male
		(n = 5)	(n = 5)	(n = 6)	(n = 5)	(n = 5)	(n = 6)
Variables		*P* Value	*P* Value	*P* Value	*P* Value	*P* Value	*P* Value
Right lateral thyrohyoid ligament (mm)	Initial and final	0.180	0.317	1.000	0.593	0.180	0.317
Left lateral thyrohyoid ligament (mm)	Initial and final	0.109	1.000	0.655	0.465	0.285	0.893
Jitter (%)	Initial and final	0.588	0.752	0.041*	0.500	0.461	0.416
Shimmer (%)	Initial and final	0.249	0.753	0.225	0.500	0.225	0.345
Fundamental frequency (Hz)	Initial and final	0.028*	0.173	0.893	0.500	0.345	0.345

* Wilcoxon test $P < 0.05$.

on vocal acoustic parameters were evidenced by the decreases in the fundamental frequency of the women in Group II who took voice training. Nevertheless, the lack of such a difference in the men in the same group may be associated with factors such as cigarette smoking, which might result in perturbations of the voice. Mendes et al[12] suggested that 2 years of voice training might be insufficient for significant changes, and age factor might cause deviations in fundamental frequencies. The wide age range of the men in Group II can be interpreted as a negative factor.

Despite the small sample size and the presence of smoking participants, the present study showed the significant effects of training on intrinsic laryngeal structures and voice quality, which suggest the need for further studies on large samples. Moreover, our recommendation for a similar research is that it is important to instruct individuals not to swallow during magnetic resonance scans, as swallowing does not allow positional changes in the hyoid.

CONCLUSIONS

Men and women have different laryngeal anatomic structures. Aging and voice training result in morphologic changes in these structures. Anatomic differences between groups showed that 8 months of training was not sufficient to trigger these morphologic changes. The left and the right LTLs were asymmetric, but this finding was not statistically significant. The length of the LTL was greater in men, and this finding supports the gender-specific differences in laryngeal structures. Improved findings in the acoustical measures in the group who took voice training suggest that chant training may be a means of improving voice quality.

Acknowledgment

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