The Immediate and Long-Term Effects of Tube and Mask+ Tube Phonation in Water Exercises and Their Duration as Measured by Electroglottographic and Nasometric Parameters

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Summary: Objective. This study investigated the immediate effects and their persistence (at 15 minutes) of various durations of semi-occluded vocal tract exercise (SOVTE) (standard tube into water and modified mask +tube into water exercises) as measured by electroglottographic (EGG) and nasometric parameters.

Methods. The study included 30 women aged 19 through 28 years with healthy voices, and it comprised five randomly implemented procedures (Ps): P1-tube phonation into water for 5 minutes; P2-tube phonation into water for 10 minutes; P3-tube+ventilation mask phonation into water for 5 minutes; P4-tube+ventilation mask phonation into water for 10 minutes; P5-phonation with ventilation mask for 5 minutes. Fifteen-minute voice rest breaks were provided between each procedure. Nasometric and electroglottographic measurements were taken before, during, immediately after and at 5, 10, and 15 minutes after the exercises, and the recorded measurements were analyzed.

Results. The immediate effects of P3 and P4 on voice quality showed better performance than the other procedures. Among all the procedures, P1 had the smallest effect on voice quality in terms of nasometric and EGG parameters and the least degree of effect permanence. In all the fluctuating SOVTE procedures except P1, the nasalance scores decreased (P1, P2, P3, and P4: fluctuating SOVTE; P5: steady SOVTE).

Conclusion. The tube phonation exercises modified by the addition of a ventilation mask were highly advantageous in terms of EGG parameters. In addition to this, regardless of the mode of application of the retention time, it was observed that the positive effect (ie, lower vertical laryngeal position) of the exercises applied for 10 minutes was higher than the exercises applied for 5 minutes.

Key Words: Semi-occluded vocal tract−Phonation into tube−Phonation into mask−EGG−Nasometer.

INTRODUCTION

In tube phonation, one of the more frequently used semi-occluded vocal tract exercises (SOVTEs) in recent years,[1,2] the level of resistance can be modified by changing the diameter and length of the tube. Allowing a better source-filter interaction further increases the favorable effects of the positive inertive reactance energy that emerges.[1,3-7]

During tube phonation, articulation is almost impossible,[1,8,9] but this limitation can potentially be overcome by forming a semi-occlusion outside the oral cavity using a modified SOVTE (eg, the combined use of a mask and a tube).[10] Some authors have examined the effects of a mechanism that combines two different SOVTE apparatus (ventilation mask and tube) and found that the effect achieved by using a water resistance ventilation mask was at the level of the positive effects of water resistance therapy (WRT) exercises. It has also been reported that SOVTEs performed with a mask provide an easier transition to continuous speech or singing, which is important for therapy generalization.[10-12]

Although researchers concur on SOVTE's positive effects on phonation, only a few studies have examined the persistence of these effects and whether it is associated with the dosage of the exercise, and the results are conflicting.[13-20] Therefore, more comprehensive studies on the topic are needed for generalizing statements. In this context, the performance duration and/or number of repetitions of exercises based on physiological voice therapy principles is crucial, because exercises of insufficient length may produce in adequate effects while vocal fatigue may develop due to vocal fold abuse when they are longer than needed.[13,14] In this area, motor learning principles are vital, especially those pertaining to the maintainability of the duration of the action. Depending on the frequency and duration of the practices, the neural connections that represent them become relatively permanent.[21] Therefore, for an exercise with limited effect persistence to be therapeutically effective and for its effect to become permanent, a "dose adjustment" is critical to promote not only motor learning but also the effectiveness of the therapy. This study used electroglottographic (EGG) and nasometric parameters to investigate the immediate effects of two types of SOVTE (standard

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tube and modified mask+tube) performed for two durations (5 and 10 minutes) and to determine their degree of persistence after 15 minutes.

METHODS

Participants

The participants comprised 30 women aged 19 through 28 years (mean age ≌ 22.43) with normal voices. The inclusion criteria for participants were as follows: Not having any parameter higher than zero level (ie, normal) according to the GRBAS results evaluated by the first and third authors who have four and five years of clinical experience and continue their doctoral education in the field of Speech and Language Therapy. The exclusion criteria were: [1] having hearing loss or an ear pathology; [2] having experienced an upper respiratory tract infection in the past 3 weeks; [3] having received professional vocal training; [4] having a history of surgery in the head and neck region; [5] having a neurological or respiratory disease; [6] having a structural pathology in the oral cavity, pharynx, or larynx; [7] having puberphonia (or a young voice); and [8] having symptoms of a cold, allergy, or reflux during the acoustic voice analysis. The application of the exclusion criteria was based on the participant's statement.

Ethical approval was obtained from the Üsküdar University, Non-Interventional Research Ethics Board (61351342/APRIL 2021-101). All participants provided written consent.

Procedure

This study used combinations of apparatus (Lax-vox tube and Mask-Vox mask) with tubes submerged in water at a depth of 5 cm. The silicone tube material had an outer diameter of 9 mm and a length of 35 cm (Lax-Vox tube). A silicone product commercially known as Mask-Vox® was selected as the mask material.[12] As the diameters of the tube and the ventilation hole of the mask were compatible, the two materials were integrated easily. A 500-mL plastic bottle was used to submerge the tube during phonation and to store the fluid.

The participants randomly performed the five distinct exercise procedures shown in Figure 1. All the measurements of each participant took 2 hours. In the procedures, for which rest and exercise durations were based on information in the relevant literature,[11,20,22] the participants were asked to first perform sustained /ʌ/ phonation for EGG recording and to read paragraphs in Turkish with successive nasal, oral, and oronasal properties.[23] The preliminary records were taken in this way. Next, the five experimental procedures were performed: (P1) /ɔ/ phonation into water for 5 minutes at a tube submersion depth of 5 cm; (P2) /ɔ/ phonation into water for 10 minutes at a tube submersion depth of 5 cm; (P3) /ɔ/ phonation into water for 5 minutes at a tube submersion depth of 5 cm with the mask +tube; (P4) /ɔ/ phonation into water for 10 minutes at a tube submersion depth of 5 cm with the mask+tube; and (P5) /ɔ/ phonation in air for 5 minutes using only the mask. Between the procedures, 15-minute relative voice rest breaks were given (with hydration). The procedures were administered to the participants in a randomized manner.

EGG records were taken during the performance of the exercises. Nasometry and EGG records were taken as in the preliminary measurements immediately after each exercise to observe the immediate effects of the exercise, and the 15-minute voice rest was provided. To determine the persistence of the performed exercise's effect, EGG measurements only were conducted after 5, 10, and 15 minutes during the voice rest period.

The EGG measurements were made using a Model 6103 electroglottograph device (Kay-PENTAX). The electrodes of the EGG device were placed at the two sides of the thyroid cartilages and secured with a Velcro strap. A 5-second record was taken of the phonation of the /ʌ/ sound at the subject's normal vocal frequency and volume, and then the middle 3 seconds of the signal were analyzed. The parameters analyzed using the EGG were the mean f_o (Hz), contact quotient (CQ) (%), average (avg.) jitter (%), and periodicity.

The nasometry measurements were taken using a Nasometer II Model 6450 device (Kay-PENTAX), which was calibrated using the calibration speaker that came with the device. The minimum calibration value was determined as 0.95 dB. During the measurement, the nasometer plate was afixed with an appliance to the participant's head in the middle of the oral and nasal regions. The participant was then asked to read the texts ather normal reading speed and with the sound volume and frequency used in daily life. The mean nasalance score (%) parameter was calculated from the nasometry measurements.

The analyses were carried out on the desktop computer (HP; operating system: Windows 7) to which the devices were connected. All the sound records were taken in the Üsküdar University Phonetics Laboratory, which is acoustically isolated.

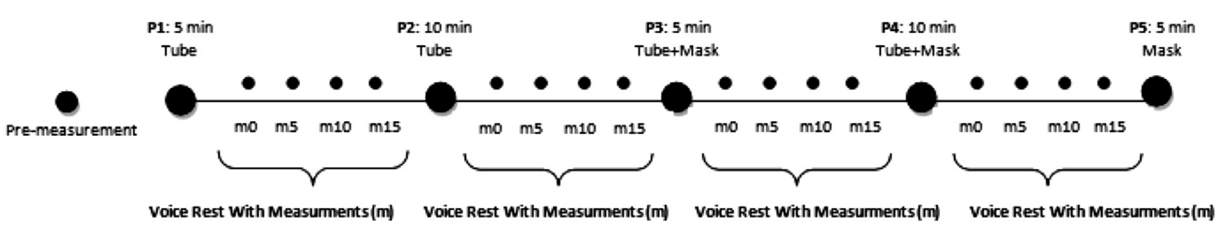

FIGURE 1. Phases of water resistance exercises performed with tube and mask+tube.

Statistical analysis

The intragroup differences of the measurements of each procedure before exercise and after exercise (immediate measurement (m0) and 5th (m5), 10th (m10), and 15th (m15) minutes) were tested using repeated-measures ANOVA. To determine the source of significant differences, based on Bonferroni correction, pairwise comparisons were made using paired-samples t-test. Additionally, to observe the combined (interaction) effects of both the procedures that were implemented and the measurements that were made before and after the exercises, two-way repeated-measures ANOVA was conducted. When interaction effects were identified, interpretation was made on main effect plots. Furthermore, pairwise comparisons were made using paired-samples t-test to analyze the measurements made before, during, and right after the exercises. The level of statistical significance for all tests was accepted as $P < 0.05$*.

RESULTS

The results of the comparison of the EGG parameters obtained during the exercise and at the m0 point after the exercise based on the procedures are shown in Table 1.

As seen in Table 1, the avg. jitter and periodicity parameters varied significantly between the measurements made during the exercise and right after the exercise ($p < 0.05$), based on the type of the procedure that was applied ($p < 0.05$), and between the measurements made during and right after the exercise based on each procedure ($p < 0.05$). The main effect plots of these interaction effects for avg. jitter and periodicity are shown respectively in Figure 2 and Figure 3.

The results of the comparison of the EGG parameters measured after the exercises based on the procedures are given in Table 2.

As seen in Table 2., the values of the examined EGG parameters that were obtained after the exercises did not show a statistically significant difference among the procedures ($p > 0.05$). The periodicity values obtained after the exercises varied significantly on a procedure basis ($p < 0.05$). The main effect plot for this relationship is given in Figure 4.

The time-dependent changes in the EGG-f_o parameter values measured before and after the exercises are shown in Table 3 for four different types of exercises.

For the P1 (5 minutes tube), P2 (10 minutes tube), P3 (5 minutes tube+mask), and P4 (10 minutes tube+mask) exercises, there were statistically significant differences among the measurements recorded before the exercise and at the m0, m5, m10, and m15 points after the exercise ($p < 0.05$). To identify the source of the significant difference found for P1, pairwise comparisons of values at different time points were made with Bonferroni correction. According to the pairwise comparison results, the significant differences in the EGG-f_o parameter were between the preexercise and m10 (t=4.328;p=0.000) measurements and between the m0 and m10 (t=4.248; p=0.000) measurements.

TABLE 1.
Comparison of the EGG Parameters Obtained During the Exercise and at the m0 Point After the Exercise Based on the Procedures

		Procedure												
		P1		P2		P3		P4		P5				
	Time	$\bar{X}$	*SS*	$\bar{X}$	*SS*	$\bar{X}$	*SS*	$\bar{X}$	*SS*	$\bar{X}$	*SS*		*F*	*p*
CQ	During exercise	44.65	3.73	44.69	3.41	42.17	4.83	42.68	4.83	45.05	4.13	Procedure	2.245	0.145
	m0	44.57	4.36	45.17	3.75	43.92	4.76	43.97	3.91	43.76	4.34	Time	1.195	0.284
												Procedure*Time	0.456	0.505
f_o	During exercise	243.17	25.79	243.47	24.12	240.57	24.67	239.20	25.30	242.43	24.54	Procedure	1.027	0.319
	m0	239.74	21.70	241.26	22.85	236.63	20.85	237.43	21.36	237.92	23.52	Time	1.988	0.170
												Procedure*Time	0.013	0.910
Avg. Jitter	During exercise	1.21	0.53	1.23	0.55	0.76	0.33	0.72	0.30	0.57	0.19	Procedure	42.589*	**<0.001***
	m0	0.70	0.44	0.64	0.32	0.66	0.29	0.66	0.40	0.57	0.20	Time	26.107*	**<0.001***
												Procedure*Time	26.261*	**<0.001***
Periodicity	During exercise	13.78	6.08	11.65	4.68	15.78	8.61	14.72	6.53	40.31	9.90	Procedure	92.880*	**<0.001***
	m0	43.56	11.47	46.23	10.12	49.07	10.62	49.36	11.82	47.97	9.23	Time	316.168*	**<0.001***
												Procedure*Time	72.757*	**<0.001***

* $P < 0.05$; CQ: Contact quotient; P1: 5 min tube into water; P2: 10 min tube into water; P3: 5 min tube+mask into water; P4: 10 min tube+mask into water; P5: 5 min mask into air.

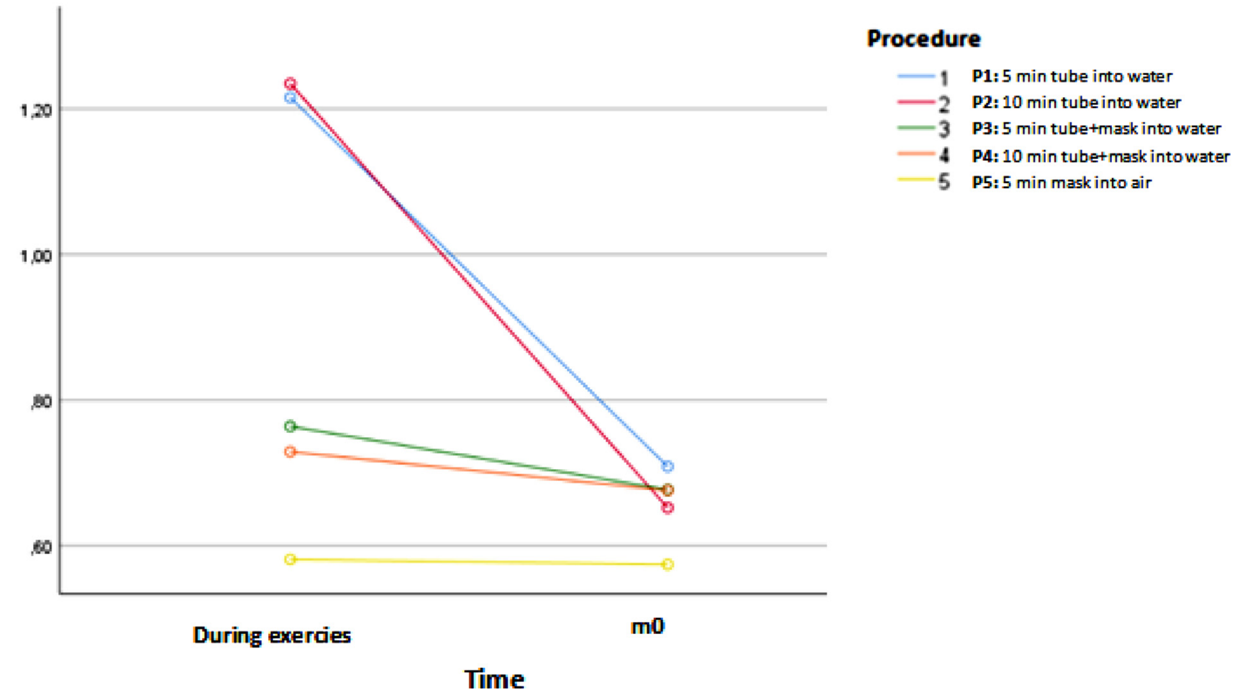

FIGURE 2. Analysis of the EGG-jitter parameter values obtained during the exercise and at the m0 point after the exercise based on the procedures.

In the pairwise comparisons with Bonferroni correction that were carried out to identify the source of the significant difference found for P2 (10 minutes tube), no significant difference could be determined. In this case, the pairwise comparisons that revealed significant differences without Bonferroni correction were taken into account, but it should be kept in mind that the error rate here was higher as no correction was made. Accordingly, the significant differences in the EGG-f_o parameter were between the preexercise and m10 (t=2.529; p=0.017) measurements, between the preexercise and m15 (t=2.178; p=0.038) measurements, between the m0 and m10 (t=2.584; p=0.015) measurements, and between the preexercise and m5 (t=2.521; p=0.017) measurements.

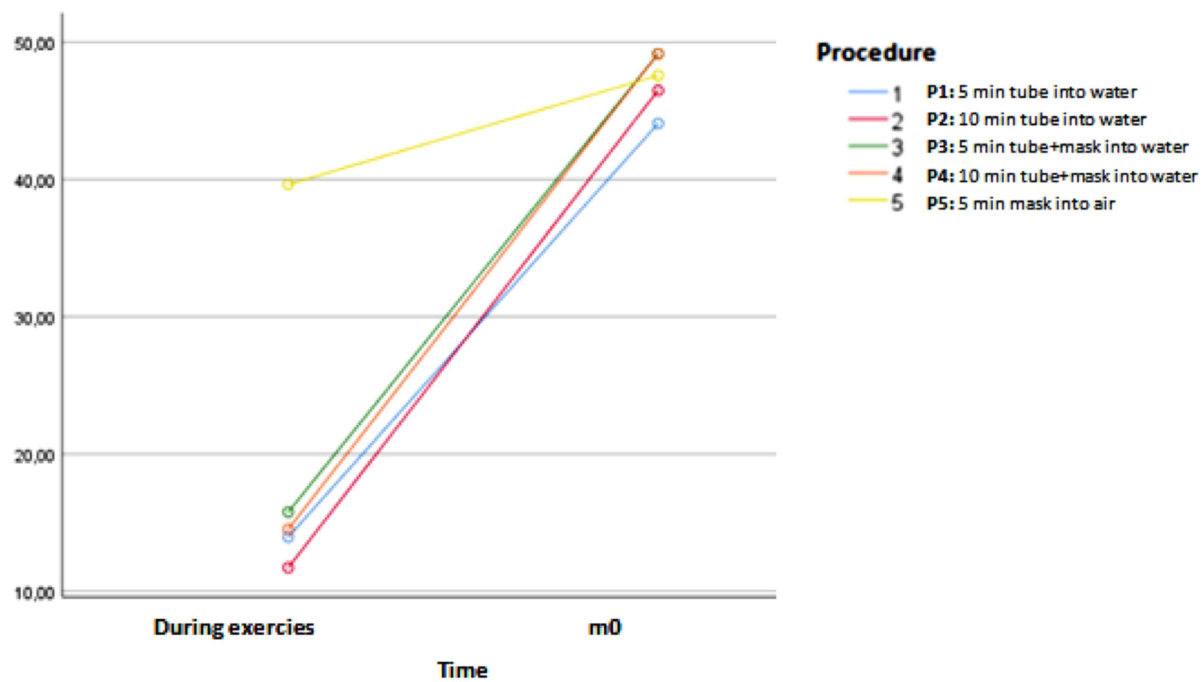

FIGURE 3. Analysis of the EGG-periodicity parameter values obtained during the exercise and at the m0 point after the exercise based on the procedures.

TABLE 2.
Comparison of the m0, m5, m10 and m15 Values of the EGG Parameters Based on the Procedures

		Procedure										
		P1		P2		P3		P4				
	Time	$\overline{X}$	SS	$\overline{X}$	SS	$\overline{X}$	SS	$\overline{X}$	SS		F	p
CQ	m0	45.17	4.36	44.57	3.75	43.92	4.76	43.97	3.91	**Procedure*Time**	0.000	0.986
	m5	45.82	3.67	45.05	4.07	45.02	3.73	44.89	3.77			
	m10	45.08	4.30	44.46	4.27	44.94	3.82	43.73	4.24			
	m15	46.29	4.38	44.58	3.58	45.41	3.67	45.10	3.58			
f_0	m0	239.74	21.70	241.26	22.85	236.63	20.85	237.43	21.36	**Procedure*Time**	2.285	0.141
	m5	235.69	20.72	239.03	22.42	236.06	21.97	236.74	22.81			
	m10	232.31	22.82	236.99	21.17	237.25	21.58	236.28	21.95			
	m15	236.28	22.55	234.94	21.52	233.87	21.96	235.66	21.40			
Avg. Jitter	m0	0.70	0.44	0.64	0.32	0.66	0.29	0.66	0.40	**Procedure*Time**	1.223	0.278
	m5	0.73	0.34	0.75	0.26	0.69	0.27	0.69	0.30			
	m10	0.75	0.49	0.65	0.45	0.69	0.32	0.59	0.25			
	m15	0.68	0.31	0.73	0.32	0.62	0.22	0.61	0.21			
Periodicity	m0	43.56	11.47	46.23	10.12	49.07	10.62	49.36	11.82	**Procedure*Time**	4.758*	**0.037***
	m5	44.44	11.46	47.00	10.27	47.20	11.05	45.95	12.03			
	m10	41.85	11.52	47.38	9.92	44.55	9.57	46.61	11.81			
	m15	46.25	10.90	47.91	11.50	45.88	9.22	46.97	10.65			

* $p<0.05$; CQ: Contact quotient; P1: 5 min tube into water; P2: 10 min tube into water; P3: 5 min tube+mask into water; P4: 10 min tube+mask into water.

To identify the source of the significant difference found for P3 (5 minutes tube+mask), pairwise comparisons of values at different time points were made with Bonferroni correction. According to the pairwise comparison results, the significant difference in the EGG-f_o parameter was between the preexercise and m10 (t=3.393; P=0.002) measurements.

In the pairwise comparisons with Bonferroni correction that were carried out to identify the source of the significant difference found for P4 (10 minutes tube+mask), no significant difference could be determined. In this case, the pairwise comparisons that revealed significant differences without Bonferroni correction were taken into account, but it should be kept in mind that the error rate here was higher as no correction was made. Accordingly, the significant differences in the EGG-f_o parameter were between the preexercise and m5 (t=2.110; p=0.044) measurements, between the preexercise and m10 (t=3.273; p=0.031) measurements, and between the preexercise and m15 (t=2.501; p=0.018) measurements.

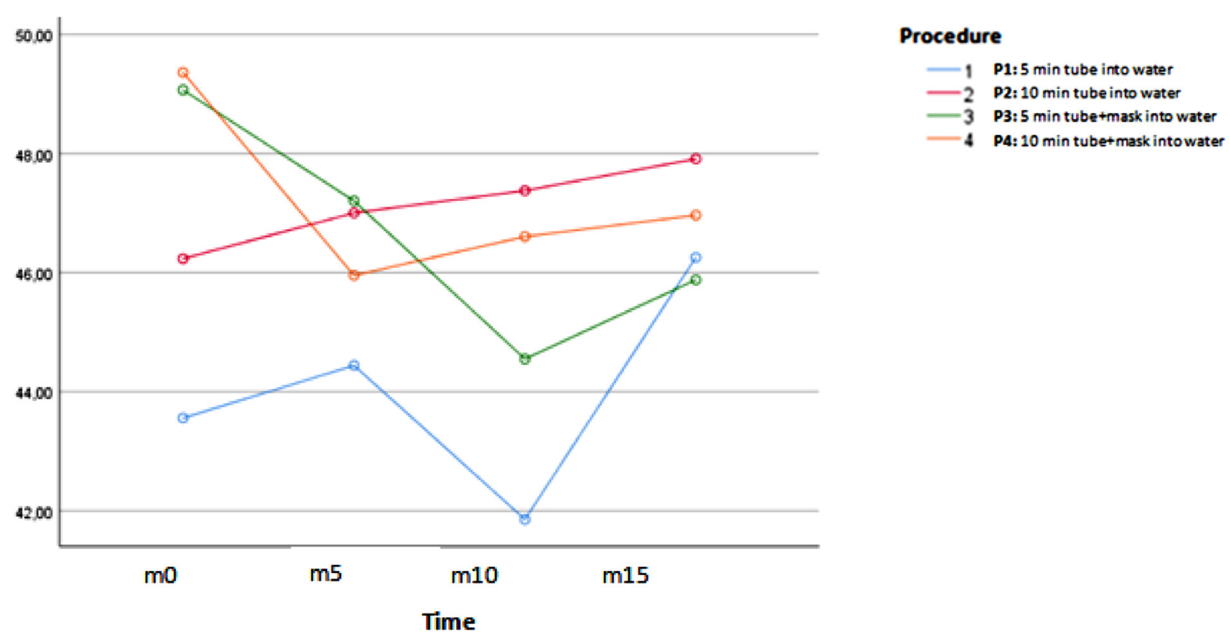

FIGURE 4. Comparison of the m0, m5, m10, and m15 values of the EGG-periodicity parameter based on the procedures.

TABLE 3.
Analysis of the Time-Dependent Changes in the EGG-f_o Parameter Before and After the Exercises

Parameter	Preexercises		m0		m5		m10		m15		*F*	*p*
	$\overline{X}$	*SS*	$\overline{X}$	*SS*	$\overline{X}$	*SS*	$\overline{X}$	*SS*	$\overline{X}$	*SS*		
f_0 (P1)	240.64	21.96	239.74	21.70	235.69	20.72	232.31	22.82	236.28	22.55	16.026*	**<0.001***
f_0 (P2)	240.64	21.96	241.26	22.85	239.03	22.42	234.94	21.17	236.99	21.52	9.034*	**0.005***
f_0 (P3)	240.64	21.96	236.632	20.855	236.06	21.97	237.25	21.58	233.87	21.96	7.698*	**0.010***
f_0 (P4)	240.64	21.96	237.43	21.36	236.74	22.81	236.28	21.95	235.66	21.40	6.127*	**0.019***

* *P*<0.05; CQ: Contact quotient; P1: 5 min tube into water; P2: 10 min tube into water; P3: 5 min tube+mask into water; P4: 10 min tube+mask into water

The results of the comparison of the EGG parameter values measured before the exercise and at the m0 point after the exercise on a procedure basis are given in Table 4.

As seen in Table 4, for all procedures, there were significant differences between the EGG-CQ values measured before the exercise and at the m0 point after the exercise ($p < 0.05$). The mean CQ value measured before the exercises ($\overline{X}$=46.27) was significantly higher than the mean values measured after the P1 (5 minutes tube), P2 (10 minutes tube), P3 (5 minutes tube+mask), P4 (10 minutes tube +mask) and P5 (5 minutes mask) exercises (respectively, $\overline{X}$=44.57, 45.17, 43.92, 43.97, and 43.76). In the periodicity parameter, while there was no significant difference between the preexercise and m0 values for P1 (5 minutes tube) ($p > 0.05$), there were significant differences for P2 (10 minutes tube), P3 (5 minutes tube+mask), P4 (10 minutes tube +mask) and P5 (5 minutes mask) ($p < 0.05$). The mean periodicity value measured before the exercises ($\overline{X}$=43.59) was significantly lower than the mean values measured after the P2 (10 minutes tube), P3 (5 minutes tube+mask), P4 (10 minutes tube+mask) and P5 (5 minutes mask) exercises (respectively,$\overline{X}$=46.23, 49.07, 49.36, and 47.97).

The results of the comparison of the nasalance scores measured before the exercise and at the m0 point after the exercise on a procedure basis are given in Table 5.

As seen in Table 5, for P2, P3, and P4, there were significant differences between the oronasal and nasal passage nasalance scores measured before the exercise and at the m0 point after the exercise ($p < 0.05$). The oronasal passage mean (%) score varied between the preexercise measurements and the measurements taken one minute after the exercise for P2, P3, and P4 ($p < 0.05$). The preexercise mean nasalance score was significantly higher than the m0 mean nasalance score. There was no significant difference between the mean preexercise and m0 oral passage nasalance scores for P1 (5 minutes tube), P2 (10 minutes tube), P3 (5 minutes tube+mask), P4 (10 minutes tube+mask) and P5 (5 minutes mask) ($p > 0.05$).

TABLE 4.
Comparison of the EGG Parameter Values measured Before the Exercise and at the m0 Point After the Exercise on a Procedure Basis

Parameter	Preexercises			m0		*t*	*p*
	$\overline{X}$	*SS*		$\overline{X}$	*SS*		
CQ	46.27	3.98	P1	44.57	4.36	2.896*	**0.007***
			P2	45.17	3.75	2.917*	**0.005***
			P3	43.92	4.76	3.543*	**0.001***
			P4	43.97	3.91	3.099*	**0.004***
			P5	43.76	4.34	3.715*	**0.001***
Avg. Jitter	0.69	0.25	P1	0.70	0.44	0.068	0.946
			P2	0.64	0.32	0.921	0.365
			P3	0.66	0.29	0.692	0.495
			P4	0.72	0.30	0.520	0.607
			P5	0.57	0.20	0.730	0.611
Periodicity	43.59	10.94	P1	43.56	11.47	.019	0.985
			P2	46.23	10.12	2.461*	**0.025***
			P3	49.07	10.62	3.056*	**0.005***
			P4	49.36	11.82	2.484*	**0.019***
			P5	47.97	9.23	2.204*	**0.036***

* *P*<0.05; CQ: Contact quotient; P1: 5 min tube into water; P2: 10 min tube into water; P3: 5 min tube+mask into water; P4: 10 min tube+mask into water; P5: 5 min mask into air

TABLE 5.
Comparison of the Nasalance Scores Measured Before the Exercise and at the m0 Point After the Exercise on a Procedure Basis

Parameter	Preexercises			m0		t	p
	$\overline{X}$	SS		$\overline{X}$	SS		
Nasal passage nasalance score	55.60	6.07	P1	55.50	6.98	0.214	0.832
			P2	52.63	7.21	4.483*	**<0.001***
			P3	53.00	7.58	3.928*	**<0.001***
			P4	53.87	7.67	2.176*	0.038
			P5	53.80	7.83	1.938	0.062
Oro-nasal passage nasalance score	43.63	5.39	P1	43.70	6.26	0.118	0.907
			P2	41.90	6.43	2.972*	**0.006***
			P3	42.23	6.97	2.242*	**0.033***
			P4	42.07	6.88	2.215*	**0.035***
			P5	43.23	6.78	0.490	0.628
Oral passage nasalance score	21.10	7.01	P1	21.23	6.75	0.180	0.858
			P2	20.37	7.45	1.098	0.281
			P3	20.37	7.50	0.962	0.344
			P4	20.83	7.87	0.377	0.709
			P5	21.97	7.89	1.069	0.294

* $P<0.05$; CQ: Contact quotient; P1: 5 min tube into water; P2: 10 min tube into water; P3: 5 min tube+mask into water; P4: 10 min tube+mask into water; P5: 5 min mask into air

DISCUSSION

According to Andrade et al (2014), SOVTEs can be divided into two distinct groups based on their physiological characteristics: steady and fluctuating SOVTE.[8] Steady SOVTE uses a single source of vibration in the vocal tract (vocal folds). Fluctuating SOVTE, by contrast, creates a constantly fluctuating supraglottal pressure that affects the vibrational modality of the vocal folds by forming a second source of vibration in the distal part of the vocal tract.[8,24] Therefore, steady SOVTE and fluctuating SOVTE have different physiological effects, and an exercise that combines the use of both may have a cumulative positive effect on the voice.

Tube phonation into water, a form of fluctuating SOVTE, creates a semi-occlusion in the oral region by extending the vocal tract, but this phonation task prevents articulation, it is limited to the generation of a single phoneme. Additionally, the oral muscles that contract to position the tube in the mouth may experience discomfort after some time. Mask or cup phonation alone, a form of steady SOVTE, is comfortable and creates a semi-occlusion in the oral region but does not reap the advantages of the greater source-filter interaction and the positive inertive energy resulting from the extension of the vocal tract with a tube.[4,1,6,7] Therefore, to ensure comfort of use and the effectiveness of the therapy as well as the transfer to speech of the new vocal behavior promoted by the therapy, modifications are required that extend the vocal tract by forming a semi-occlusion outside the oral cavity in addition to allowing phonation into water. Only a limited number of studies have investigated the perceptual, aerodynamic, and acoustic effects of the integrated use of the mask+tube modification, [10-12] so in this study examined the effects on EGG and nasometric parameters of different durations of exercise performed with only a tube and with a mask+tube combination.

Interpretation of electroglottographic findings

The EGG measurements of vocal fold movements recorded before and immediately after the exercises indicated that the average jitter and periodicity values varied depending on the implemented procedure, and they revealed an interaction effect between the implemented procedures and the times of their measurement. The highest jitter values were obtained with the P1 and P2 procedures (implemented with only a tube), which used only fluctuating SOVTE, while much lower jitter values were observed for the P3 and P4 procedures (mask+tube), in which fluctuating and steady SOVTE were combined. The lowest jitter values were recorded for the P5 procedure (implemented with only a mask), a form of steady SOVTE.

The highest frequency perturbation were observed for the exercises implemented with only a tube (P1 and P2) while much lower frequency perturbation were recorded for exercises in which tube phonation was combined with mask phonation, and the lowest frequency perturbation values were seen in the steady SOVTE (P5). This result supports the researchers who categorized SOVTE as fluctuating and steady.[8,24,25]

Moreover, Figure 2 shows that the jitter parameter values of all the procedures followed negative slopes from their measurement during the exercise to their measurement after the exercise. In other words, the jitter values recorded during the exercise fell when measured immediately after the exercise. This was expected, but a highly striking and important finding is that the exercises with the steepest slopes were those using only tubes while the exercises using the mask+tube combination had much shallower slopes, and the exercise with only a mask had a slope angle of almost zero degrees. This result indicates that adding the mask to the exercises conducted with tubes reduced the jitter values substantially and increased the stability of the vocal fold. Due to intraoral pressure changes, the trans-glottal pressure also changes as a result of WRT, and this change results in an additional modulation in the vibrations of the vocal folds.[25,26] For this reason, it is believed that the decrease in jitter values associated with adding ventilation mask phonation (a form of steady SOVTE) to WRT (a form of fluctuating SOVTE) (P3 and P4) was caused by the more stable vocal fold vibrations that occurred with the lower degree of intraoral pressure fluctuation as well as the more stable trans-glottal pressure originating in this.

A similar situation was seen in the EGG-periodicity parameter. The procedures done with tubes only (P1 and P2) yielded the lowest periodicity values in the measurements taken during the exercise while higher values were observed in the exercises carried out with the mask+tube combination (P3 and P4), and the highest periodicity value during the exercise was found in the procedure using only the mask (P5). This finding reflects the results of the EGG-jitter values and their interpretation. In this case, it was expected that the procedure using only the mask (P5) (a form of steady SOVTE) would have the highest periodicity value among all the procedures,[8,24,27] because steady SOVTE performed with only a mask yields less variable oral pressure (Poral) values than fluctuating SOVTE performed by phonation into water, and it is believed that this situation causes reduced frequency perturbation (jitter). Furthermore, the lower periodicity and higher EGG-jitter values of the fluctuating SOVTE in comparison with the mask+tube combination supports our inference that adding a mask to tube phonation reduces the momentary poral change during the exercise and increases the stabilization of pressure change. Similarly, the semi-occlusion of the vocal tract leads to increased subglottal pressure and reduced trans-glottal pressure.[28,29] This aerodynamic change, which helps the vocal folds stay slightly in abduction, is expected to produce a lower vocal fold CQ.[6,29] Likewise, a decrease in the phonation threshold pressure (PTP) is characterized by a decrease in the minimum subglottal pressure required to induce phonation, and this situation has been observed as an effect that makes the action of phonation easier.[11,30,31] In a study that examined the integrated effects of the mask +tube combination under ex vivo conditions, the authors concluded that attaching a mask to the tube does not lead to a loss in vocal economy or vocal efficiency.[11] Additionally, two other studies based on perceptual and acoustic examinations support the integrated use of the mask+tube modification, reporting the method's positive effects on the parameters.[10,12]

This study's comparison of the preexercise and post-exercise EGG-periodicity parameter values found that the latter increased in comparison to the former in all the procedures except P1 (ie, P2, P3, P4, and P5) (Table 4). In addition, in terms of the mean values, P3 and P4 yielded higher periodicity values than P1 and P2 (Table 1 and Figure 3). This result indicates that the inclusion of a mask in tube phonation exercises may support a more regular vocal fold movement by increasing the vocal fold periodicity value, one of the immediate positive effects observed after the exercise. Studies performed with semi-occluded facemasks (SOFMs) have also mentioned the positive effects of exercise on the voice.[22,31-34]

The result obtained for the EGG-CQ values also support our inference. A reduction in the vocal fold closure rate after exercise indicates a more regular closure of the vocal fold and less mechanical stress.[29] Our results confirm this phenomenon, as the CQ values after all the exercises were lower than those recorded before the exercises. Our results are also compatible with those of other studies that have reported reductions in EGG-CQ values during and/or after WRT, a form of fluctuating SOVTE.[25,35,11] Considering only the mean values of the measurements taken immediately after the exercise without significant differences within procedures, the P3 and P4 procedures yielded lower EGG-CQ values than did P1 and P2 (Table 1 or Table 4). This finding also supports the idea that integrating a mask into the tube phonation procedure may yield a more positive effect in terms of vocal fold movement patterns than performing tube phonation exercises alone.

Our final result that supports his inference is found in the joint effect values and the plot of the changes in the EGG values recorded for the periodicity parameter at various times after the exercise (shown in Table 2.) for each procedure (Figure 4). In the measurements made at the m0 point, which could be considered an immediate effect, the periodicity values of the P3 and P4 implementations were higher than those of P1 and P2. The lowest periodicity values were found in the P1 procedure.

Interpretation of nasometric findings

SOVTE exercises also affect velopharyngeal function and facilitate an increase in velopharyngeal closure. Previous studies have also found a high degree of velopharyngeal closure, a vertically lowered larynx, and increased cross-sectional areas of the hypopharynx.[35,36] In this context, the data in Table 5 indicate that only procedures P2, P3, and P4 decreased the nasalance scores, especially for the nasal and oronasal texts, in addition to increasing the velopharyngeal closure in the measurements taken at the m0 time point compared to the preexercise measurements. This result suggests that P1 maybe an inadequate procedure for enhancing the regular movement of the vocal fold (periodicity) and increasing velopharyngeal closure. The P5 procedure was also found to be insufficient for the purpose of increasing velopharyngeal closure only.

Interpretation of findings regarding the duration of application of SOVTE procedures and the duration of effect after exercise

In the results showing the long-term effects after exercise, especially in the measurements at the m10 and m15 time points, fluctuating SOVTE performed for 10 minutes yielded higher periodicity values than fluctuating SOVTE performed for 5 minutes regardless of the procedure (Figure 4). This suggests that, while the immediate effects observed (especially in fluctuating SOVTE) are closely associated with the form of exercise implemented, the long-term effects may depend on the duration of the exercise. Regarding the long-term positive effects of the different fluctuating SOVTE exercises done for various durations, the results for the EGG-f_o parameter support the inferences drawn about the persistence of the positive effects that were achieved. A lower vertical laryngeal position (VLP), one of the positive effects of SOVTE, may be a consequence of the relaxation of the laryngeal and pharyngeal muscles.[35,37] A high VLP is prevalent in individuals with voice disorders characterized by muscle strainity, because excessive strain in the extrinsic laryngeal muscles that keep the larynx in suspension can pull up the larynx.[38-41] A higher VLP has potentially negative effects on phonation.[42] It has been noted that the aims of voice therapy (especially voice therapy implemented with SOVTE) include a lower larynx, relaxation of the laryngopharyngeal muscles, and a vocal tract broadening in the pharyngeal region.[29,35] In this case, a larynx with a lower vertical position is expected to be characterized by a reduction in the fundamental frequency. As shown in Table 3, the fluctuated SOVTEs (independently of how it was implemented) found that the low f_o values of the procedures implemented for 5 minutes (P1 and P3), which could predict a lower VLP, persisted until the m10 time point. The low f_o values of the procedures implemented for 10 minutes (P2 and P4), which could also predict a lower VLP, were observed until the m15 time point. Thus, the greater persistence of an exercise's VLP effects appears to depend more on the duration of the exercise than on its form of implementation.

In a study employing a similar methodology, 24 participants performed tube phonation exercises for 5 minutes and 10 minutes. Aerodynamic, acoustic, and EGG parameters were measured in 20 minutes time frame after the exercises were completed. The results indicate that the lower PTP values after the 10-minute tube phonation exercise (compared to the preexercise values) had more persistent effects than those of the 5-minute tube phonation exercise, which could be explained by motor learning principles.[17] Similarly, the researchers in a study of SOFMs report that 5 minutes of phonation performed using a ventilation mask with a diameter of 6.4 mm resulted in a greater and more consistent increase in the acoustic-cepstral peak prominence (CPP) parameter than a 2-minute implementation.[22] A study that did not identify an acoustic improvement effect from a 3-minute tube phonation exercise also supports these results.[16] Thus, our results, which indicate that the persistence of SOVTE's positive effects increases with a longer duration of implementation, align with the results of the aforementioned studies on the persistence of SOVTE's effects.

It remains crucial to identify the ideal duration of SOVTE implementation and to determine whether that duration varies on the basis of age and sex. A study with child participants found that the ideal duration of tube phonation exercises is 3−5 minutes while a duration of 7 minutes can shorten the maximum phonation time and cause fatigue.[18] A study conducted with only women found that perceptually evaluated voice quality did not change among participants with healthy voices as a result of exercises performed for 7 minutes,[19] while another study found a worsened perceptually evaluated voice quality in women after 7 minutes of exercise but found no significant change in men.[15]

These inconclusive results indicate a need for mixed-method studies on the duration of SOVTE exercises in which qualitative and quantitative results are evaluated together to take into account the subjectivity of perceptual evaluation while determining the immediate positive effects by using EGG and aerodynamic parameters as objective measures for identifying the persistence of the positive effects.

CONCLUSION

The major findings from this study are as follows:

The immediate and long-term effects of fluctuating SOVTE differ, and our results suggest that combined mask +tube into water exercises may be more beneficial than exercises using only a tube, especially in increasing the periodicity of vocal fold movement patterns.

The least effective exercise for increasing the periodicity of the vocal folds and velopharyngeal functions was the tube phonation exercise performed for 5 minutes.

All the SOVTE procedures performed in this study reduced the EGG-CQ values, indicating that all the procedures effectively reduced mechanical stress in the vocal folds.

Additionally, the lower fundamental frequency values (in comparison to the initial values) obtained from the tube-only and mask+tube procedures performed for 10 minutes (which can indicate a lower vertical position of the larynx) were preserved in the measurements taken at 5, 10, and 15 minutes after the exercise. This shows that the positive effect resulting in the relaxation of the extrinsic and intrinsic laryngeal muscles (which are associated with laryngeal muscle tension and/or higher laryngeal positioning) may continue for up to 15 minutes after exercises performed for 10 minutes.

All the results reported here emphasize the importance of SOVTE practices that are tailored to the person, situation, and case. Finally, to the best of our knowledge, this study is the first to use EGG and nasometric parameters to investigate differences in the effects of mask+tube into water exercises on the basis of different implementation durations and between different procedures.

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