Original Article

Artigo Original

Dosage dependent effect of high-resistance straw exercise in dysphonic and non-dysphonic women

Efeito do tempo de realização do exercício de canudo de alta resistência em mulheres disfônicas e não disfônicas

Sabrina Mazzer Paes[1]
Mara Behlau[1,2]

Keywords

Voice
Voice Disorders
Dysphonia
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Exercise

ABSTRACT

Purpose: to study the dosage dependent effect of high-resistance straw exercise in women with behavioral dysphonia and in vocally healthy women. **Methods:** 25 dysphonic women (DG), with average age of 35 years (SD = 10.5) and 30 vocally healthy women (VHG), with average age of 31.6 years (SD = 10.3). The participants produced a continuous sound into a thin high-resistance straw for seven minutes, being interrupted after the first, third, fifth and seventh minute. At each interval, speech samples were recorded (sustained vowel and counting up to 20) and subsequently acoustically analyzed. Each participant reported the effort necessary to perform exercise and to speak, indicating their ratings on visual analog scales (VAS). **Results:** with regard to the DG, the exercise caused positive vocal changes, especially between the third and fifth minute: less phonatory effort, increase in MPT, and reduction of F_0 variability; these voice parameters deteriorated after five minutes. This fact associated with the increased effort to perform the exercise indicates a possible overload of the phonatory system. As to the VHG, MPT improved after one minute of exercise, while the other parameters did not change over time, probably due to the fact that the voices were not deviant; seven minutes did not seem to impose an overload in this population. **Conclusion:** positive vocal changes were observed with the high-resistance straw exercise; however, there are dosage restrictions, especially for dysphonic women.

Descritores

Voz
Distúrbios da Voz
Disfonia
Treinamento da Voz
Exercício

RESUMO

Objetivo: Verificar o efeito do tempo de realização do exercício de canudo de alta resistência em mulheres com disfonia comportamental e em mulheres vocalmente saudáveis. **Método:** As participantes, 25 mulheres disfônicas (GD), com idade média de 35 anos (DP = 10,5) e 30 mulheres vocalmente saudáveis (GVS), com idade média de 31,6 anos (DP = 10,3), emitiram um som contínuo em um canudo de alta resistência por 7 minutos, com interrupções depois de 1, 3, 5 e 7 minutos. Amostras de vogal sustentada "é" e contagem de números foram registradas (FonoView-4.6, CTS) antes do início da realização do exercício e depois de cada uma das séries. Posteriormente, foram analisadas acusticamente. Cada participante foi orientada a prestar atenção no esforço fonatório aplicado durante o exercício, bem como na fala, registrando sua intensidade em uma escala analógico-visual (EAV). **Resultados:** Para o GD, houve predomínio de respostas positivas após 3 minutos de exercício, com melhora do esforço para falar, aumento do TMF e redução da variabilidade de F_0; com a continuidade do exercício, esses parâmetros pioraram, sugerindo sobrecarga no sistema, e o esforço fonatório percebido no exercício piorou gradativamente com o tempo. Para o GVS, o único parâmetro que se modificou foi o TMF, que melhorou após 1 minuto; 7 minutos não parece significar sobrecarga para essa população. **Conclusão:** Foram observadas modificações vocais positivas com o exercício de canudo de alta resistência, mas há limites quanto a sua dosagem. Deve-se observar efeitos não desejados para evitar sobrecarga vocal desnecessária, principalmente em mulheres disfônicas.

Correspondence address:
Sabrina Mazzer Paes
Rua Botucatu, 802, São Paulo (SP), Brazil, CEP: 04023-062.
E-mail: samapaes@hotmail.com

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Study carried out at Departamento de Fonoaudiologia, Universidade Federal de São Paulo – UNIFESP - São Paulo (SP), Brazil.

[1] Universidade Federal de São Paulo – UNIFESP - São Paulo (SP), Brazil.

[2] Centro de Estudos da Voz - São Paulo (SP), Brazil.

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INTRODUCTION

Vocal training is an intervention for improvement and rehabilitation which aims for a production with minimum effort and maximum efficiency[1]. Normally, it involves daily exercises, acquisition and generalization of techniques for better vocal production, elimination of harmful vocal behaviors and, in some cases, reducing use of speech and voice[2,3].

Recent technological advances in Laryngology have provided great scientific contribution to the field, resulting in a wide range of existing treatment options[3]. However, data on efficacy and prescription of these treatments is still limited[2,4-6]. This gap is assigned to several issues: in terminology, definition, flaws in the statistical basis, lack of control groups and standardization of procedures among studies, such as exercise dosage and duration of treatment[6].

Vocal exercise physiology is a field not yet well developed due to the specific features of the laryngeal musculature. However, the principles of physical training can be used for vocal training, although there are particularities in vocal production compared to the activity of other body muscles[7]. There are four components to be considered in a physical training program: frequency (number of repetitions of a training per day or week), duration (time for completion of an exercise or number of repetitions of a series), intensity (type of exercise in terms of the necessary effort) and progression of the exercises[8]. In vocal training, there is little scientific evidence on the combination of these four components. Therefore, exercises are still prescribed based on the therapist's clinical experiences.

The principle of overload in physical training stipulates that the work required from muscles must be greater than that performed in daily use, with insertion of additional load consistent with the individual's level of physical conditioning. Therefore, it is necessary to adjust exercise dosage in terms of the duration and intensity of the activity, in order to make expected results attainable. Excessive overload is harmful and may cause considerable damage to the organism, such as muscle overheating and inflammatory response[8]. Concurrently, inadequate recommendation as to the time (duration) of vocal exercises with a particular intensity may harm the evolution of vocal training[7]. Opting for a duration above the ideal for an exercise may render treatment innocuous, while excessive duration may cause the system to overload, resulting in signs and symptoms of vocal fatigue[4,5].

In addition to individual issues in responding to the vocal exercises prescribed[9], each voice exercise has a different effort level. For instance, some exercises provide higher resistance to air flow as they are executed, since they are produced with semi-occluded anterior vocal tract, which increases glottal excitation and muscle activity of the larynx[10,11]. These are the so-called semi-occluded vocal tract exercises (SOVT Exercises), such as the production of closed vowels "i" and "u", nasal sounds, sonorous lip and/or tongue vibration technique, bilabial fricatives, labial constriction, finger kazzo, glottal firmness, and phonation in straws and tubes with different diameters and lengths[12-16].

SOVT exercises have been present in the literature for over 50 years, with accounts from the 19th and 20th centuries. However, a growing interest is observed in the last two decades. Today, it is known that SOVT exercises favor interaction between the glottis and supraglottis, causing voice to be produced in an economic and efficient manner. For this reason, they are indicated for people who need to improve vocal conditioning due to prolonged daily use of their voice[10,11,15-20].

Few SOVT exercises have been tested as to time of administration: for the sonorous tongue vibration technique, three studies in the literature point to a predominance of positive responses in the 3rd minute for non-dysphonic women[4], and in the 5th minute for dysphonic women with vocal nodules[5] and non-dysphonic men[4]. This data is of great importance to guide speech therapists in the construction of vocal training programs. Unfortunately, there are no detailed studies for other techniques.

It is known that, the higher the air flow resistance in the anterior vocal tract, the higher the effort necessary for its accomplishment - which calls for more careful dosage. Although this aspect is acknowledged[4,5,11,21-23], information is insufficient to substantiate prescription of these exercises.

One of the SOVT exercises with higher resistance to air flow is the exercise of phonation into a narrow rigid straw[15,17,19-25], which is also the one with most widely proven short-term positive effects[1,11,15,19,21]. Additionally, it is low-cost and easy to perform, being indicated for practice several times a day, for 2 to 5 minutes, both for vocal improvement and rehabilitation of voice changes. Nevertheless, this prescription is based on clinical experience and empirical rules and thus lacks detailed studies on the effect of exercise dosage in dysphonic and non-dysphonic voices.

For this reason, this study aimed to verify the effect of high-resistance straw exercise dosage in women with behavioral dysphonia as well as in vocally healthy women.

METHODS

This study was approved by the Research Ethics Committee of Universidade Federal de São Paulo - Unifesp (596/11) and all volunteers have signed the Informed Consent Form.

Fifty-five women aged between 20 and 50 years old have taken part in this study, divided into two groups: 25 women in the group of dysphonic individuals (DG), with average age of 35 years (SD = 10.5), who sought medical assessment and treatment due to voice problems; and 30 women in the vocally healthy group (VHG), with average age of 31.6 (SD = 10.3), who attended the same medical service as patient escorts in the same period. The statistical analysis showed that the DG and VHG were not statically different in terms of age ($p = 0.236$).

The inclusion criteria for the DG were: vocal complaint, alteration in voice quality assessed by voice triage by means of auditory-perceptual analysis carried out after sample collection, otorhinolaryngological diagnosis of chronic behavioral dysphonia with indication for speech therapy, and lack of previous voice treatment.

The inclusion criteria for the VHG were: lack of vocal complaint, neutral vocal quality assessed by voice triage by means of auditory-perceptual analysis carried out after sample collection, absence of treatable laryngeal alteration according to otorhinolaryngological assessment performed by the same team of Setor Interdepartamental de Laringologia e Voz of Unifesp, and lack of previous voice treatment. Two volunteers were excluded for presenting incipient nodules.

All participants filled out an identification questionnaire as well as a list of Vocal Signs and Symptoms, in which the DG volunteers should have presented 3 or more signs and symptoms, while the VHG participants should have checked a maximum of 2 in order to remain in the research. These scores were previously obtained according to the Brazilian population figures[15]. The average number of signs and symptoms for the DG was 6.9 (SD = 2.3), and for the VHG, 0.9 (SD = 0.8).

The exclusion criteria for both groups were: being or having been a smoker, presenting upper respiratory tract infection or any respiratory disease on the day of their participation in the study, being in the premenstrual period, having been diagnosed with psychiatric or cognitive disorders. In addition, participants who would not abide by the study's procedures would also be excluded (two volunteers for DG have been excluded).

Each participant was given a commercially available rigid plastic straw with 8.7 cm in length and 1.55 mm in diameter (THEOTO S/A Ind. e Com.) and was asked to hold it between their teeth, with lips closed, while producing an undifferentiated sound, similar to "vu", in a comfortable frequency and intensity. After the exercise was demonstrated by the researcher, each participant was asked to do the exercise keeping phonation for a long and comfort period of time, breathing when necessary, for up to 1 minute. Fifteen seconds before the 1-minute period expired, the researcher asked participants to pay attention to the phonatory effort applied at that moment of the exercise. As soon as time was up, the participant was asked to indicate on a 100 mm-visual analog scale (VAS) the representation of that effort, where 0 (zero) means "no effort" and 100, "maximum effort".

Three other similar series were carried out in sequence, but this time with a duration of 2 minutes each. Cumulatively, they add up to 1, 3, 5, and 7 minutes of exercise in four series (s1, s3, s5, and s7)[4,5] with a minor interval in between, necessary only to note the intensity of effort during the exercise and for vocal recording. The maximum time for completion of the exercise was limited to 7 minutes, as studies carried out with other SOVT exercises identified symptoms of vocal fatigue after this period[4,5].

Speech samples were recorded directly on a portable computer, with software FonoView-4.6 (CTS Informática), at recording sample rate 44.1, with a unidirectional headset microphone (Karsect HT-2) positioned at 45 degrees and placed at 5 cm from the speaker's mouth, connected to an external sound card (Andrea PureAudio USB) in a silent environment used for all recordings.

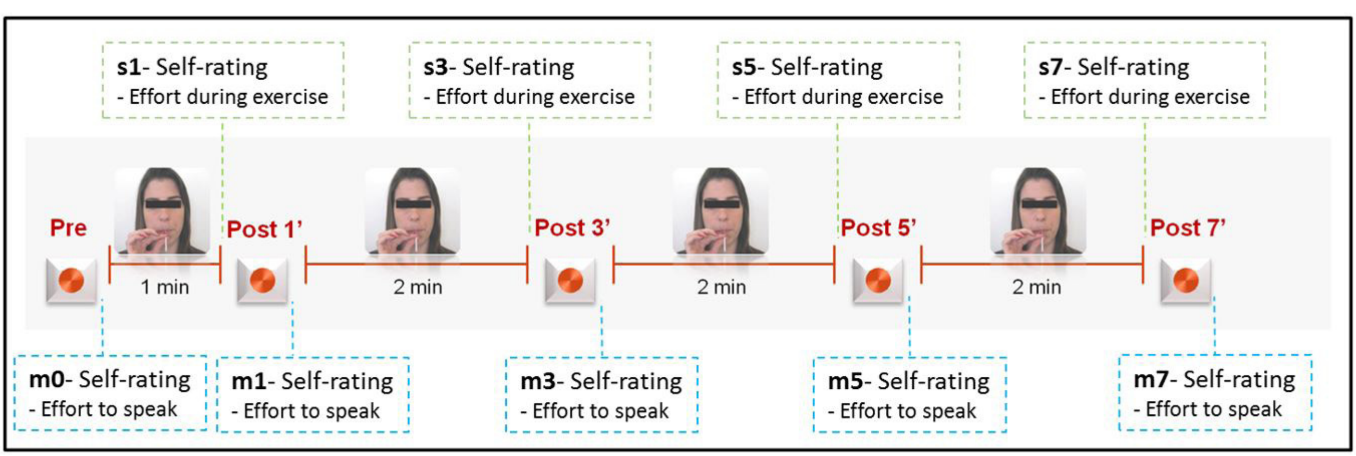
The spoken material registered was the vowel "e", sustained for as long as possible, and counting from 1 to 20 on habitual frequency and intensity. These recordings were collected before the beginning of exercises and after each series (after 1, 3, 5 and 7 minutes). Thus, five samples of speech from were collected for each participant.

Before each vocal recording, the volunteers were instructed to pay attention to the effort necessary to speak at that moment (m0 = pre-exercise; m1 = after 1 minute; m3 = after 3 minutes; m5 = after 5 minutes; m7 = after 7 minutes), since afterwards they would be asked to indicate their intensity on a 100mm VAS.

Vocal effort was understood in this work as a feeling of tightness on the throat, pain, or discomfort to speak, as well as an effort inconsistent with the vocal result. This information was passed on to the volunteers before the beginning of the first vocal recording (m0).

In order to ease visualization of the stages of data collection, a schematic drawing was designed, which is presented in Figure 1.

In order to verify the presence or absence of vocal alteration according to the auditory-perceptual analysis of DG and VHG's speech samples, respectively, 3 speech therapists specializing in Voice, with over 10 years' clinical experience, analyzed the excerpts of counting from 1 to 10 before the exercise by means of the 100mm VAS, where 0 (zero) means "absence of vocal



Caption: = recording of speech samples; = exercise performance; min = minute; m0 = pre-exercise; m1 = after 1 minute; m3 = after 3 minutes; m5 = after 5 minutes; m7 = after 7 minutes; s1 = 1 minute of exercise; s3 = 3 minutes of exercise; s5 = 5 minutes of exercise; s7 = 7 minutes of exercise

Figure 1. Schematic drawing indicating the stages of data collection

alteration", and 100 means "extreme vocal alteration". These extracts were edited from the counting from 1 to 20 with the aid of software VoxMetria-4.0 (CTS Informática). A 36% (20) repetition rate was predicted for the intraobserver reliability analysis, which was equal to 70% for observer 1, 75% for observer 2, and 90% for observer 3. Thus, the data generated by observer 3 was considered. No samples were excluded at this stage, since all samples from DG were classified as deviated (above 35.5 mm, average = 56.2 and SD - 19.2). The samples from VHG were considered as within normal variability range (0 to 35.5mm, average = 25.9 and SD = 9.0).

A pilot project was carried out with 6 individuals who would compose DG and 8 individuals who would compose VHG, in order to determine details and adjust procedures. These individuals were not included in the final sample of this study.

The scale was colored according to an existing scale widely used for subjective perception of effort in sports medicine, the BORG scale[26], which presents a five-color gradient: blue, green (cool colors, which refer to low symptom intensity), yellow, orange, and red (warm colors, which refer to an increase in symptom intensity).

The effect of the exercise at different times (pre-exercise, after 1, 3, 5, and 7 minutes) was verified by means of subjective self-rating of phonation effort as well as by means of acoustic analysis of the sustained vowel samples.

For analysis of the subjective self-rating of phonation effort, during speech and during the exercise, the 100mm VAS scores were extracted from the self-rating protocol.

For the acoustic analysis, 3-second excerpts from the sustained vowel "e" were used. The first second produced was eliminated, since it may present irregularities typical of the vocal attack (onset of tone) phase, as well as the remaining final extract. Editing of the sustained vowel and extraction of measurements were carried out by the researcher herself, as these do not rely on personal interpretation, using software VoxMetria-4.0 (CTS Informática). The acoustic parameters selected were maximum phonation time - MPT (extracted from the integral samples of the sustained vowel "e" as an exception to the other acoustic parameters, which were extracted from the excerpts of 3 seconds of vowel, edited by the researcher, as mentioned above), fundamental frequency (F_0) and its variability (Hz and semitones), jitter, shimmer, GNE (glottal to noise excitation), noise and irregularity.

The data was statistically analyzed by means of an ANOVA with repeated measures and a 5% level of significance. For the analyses in which significant differences were found ($p < 0.05$), Tukey's Multiple Comparison test was used to compare the moments in pairs.

RESULTS

Self-rating

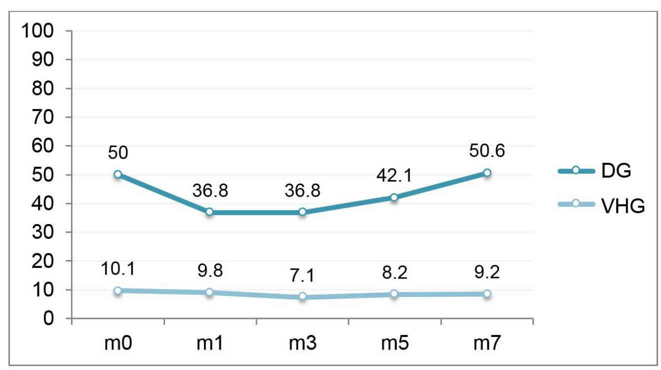
The effort to speak in DG (Table 1) changed over time: it improved after 1 and 3 minutes of exercise and got worse again with continued exercise, resuming initial intensity after 7 minutes. In the VHG, however, the effort remained the same (between 7.1 and 10.1 out of 100) from beginning to end. This difference between the two groups' responses, both in gross values (DG's values were higher than VHG's) and between the evolution curves of the responses, is evidenced in Figure 2.

As to the phonatory effort perceived during the exercise (Table 2), its intensity also changed for the DG, while it remained the same for the VHG from beginning to end (between 15.2 and 22 out of 100). The DG felt the presence of effort load in the exercise from the first minute, and the effort increased progressively over time. Figure 3 indicates the difference between responses of the two groups, both in gross values (DG's values were higher than VHG's) and between the evolution curves. Although it seems that the effort to perform the exercise increased over time also for the VHG, the statistical analysis did not indicate this result.

Acoustic analysis

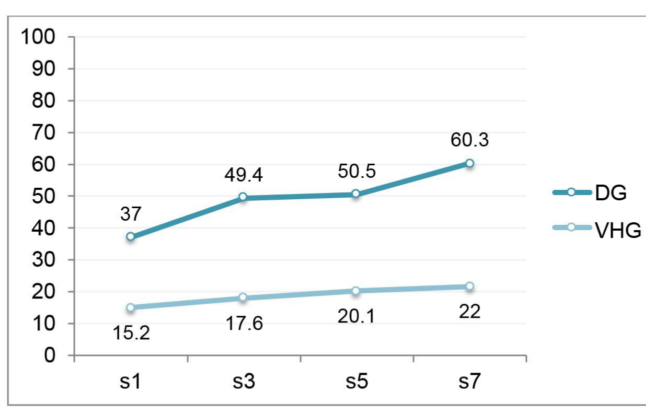
For the DG (Table 3), the exercise modified two acoustic parameters: MPT and F_0 variability, with an improvement after 3 and 5 minutes and worsening after 7 minutes.

For the VHG (Table 4), the only parameter modified over time was MPT, which improved after 1 minute of exercise and remained higher up to the end.



Caption: DG = group of dysphonic individuals; VHG = group of vocally healthy individuals

Figure 2. Progress of self-rating of effort to speak at each moment (m0, m1, m3, m5 e m7) for both groups, DG and VHG



Caption: DG = group of dysphonic individuals; VHG = group of vocally healthy individuals

Figure 3. Progress of self-rating of phonatory effort during exercise at the end of each series (s1, s3, s5, and s7) for both groups, DG and VHG

Table 1. Results of self-ratings as to effort to speak for the DG and VHG at each moment (m0, m1, m3, m5 e m7) and comparison among them

Effort to speak	m0	m1	m3	m5	m7	Anova (P value)	Tukey's Multiple comparison
DG							
Mean	50.0	36.8	36.8	42.1	50.6	<0.001*	m0 > m1 = m3 < m5 < m7
SD	15.7	18.3	17.9	22.6	25.4		m0 > m5 I m0 = m7
VHG							
Mean	10.1	9.8	7.1	8.2	9.2	0.517	NA
SD	8.9	7.9	5.3	6.3	8.3		

*Statistical significance ($p<0.05$)

Caption: DG = group of dysphonic individuals; VHG = group of vocally healthy individuals; m0 = pre-exercise; m1 = after 1 minute; m3 = after 3 minutes; m5 = after 5 minutes; m7 = after 7 minutes; SD = standard deviation; NA = not applicable analysis

Table 2. Results of self-ratings as to phonatory effort during the exercise for the DG and VHG at the end of each series (s1, s3, s5 and s7) and comparison among them

Phonatory effort during exercise	s1	s3	s5	s7	Anova (P value)	Tukey's Multiple comparison
DG						
Mean	37.0	49.4	50.5	60.3	<0.001*	s1 < s3 = s5 < s7
SD	25.2	25.5	27.6	25.2		
VHG						
Mean	15.2	17.6	20.1	22.0	0.293	NA
SD	14.2	13.3	14.7	15.2		

*Statistical significance ($p < 0.05$)

Caption: DG = group of dysphonic individuals; VHG = group of vocally healthy individuals; s1 = 1 minute of exercise; s3 = 3 minutes of exercise; s5 = 5 minutes of exercise; s7 = 7 minutes of exercise; SD = standard deviation; NA = not applicable analysis

Table 3. Mean and standard deviation of acoustic parameters of DG according to each moment (m0, m1, m3, m5 e m7) and comparison among them

Parameters	m0	m1	m3	m5	m7	Anova (P value)	Tukey's Multiple comparison
MPT (s)				9.71	8.14		
Mean	9.01	9.05	10.37	2.41	1.94	0.002*	m0 = m1 < m3 = m5 > m7
SD	2.80	2.38	2.40				m0 e m1 > m7
F_0 (Hz)				200.6	197.1		
Mean	196.9	193.9	195.0	31.5	24.4	0.240	NA
SD	28.3	24.4	22.3				
Variability of F_0 (Hz)	16.73	17.41	10.77	10.11	22.86	0.041*	m0 = m1 > m3 = m5 < m7
Mean							
SD	13.37	17.76	9.06	6.88	41.70		m0 and m1 < m7
Variability of F_0 (semitones)						0.166	NA
Mean	1.56	1.60	1.08	0.84	1.84		
SD	1.61	1.61	0.81	0.85	3.30		
Jitter (%)							
Mean	0.88	1.00	1.32	0.41	0.40	0.379	NA
SD	2.42	2.68	2.75	0.90	0.64		
Shimmer (%)							
Mean	3.69	4.76	4.81	3.04	3.21	0.386	NA
SD	4.79	7.87	5.51	2.85	2.63		
GNE							
Mean	4.08	0.68	0.66	0.69	0.69	0.629	NA
SD	17.07	0.24	0.23	0.21	0.21		
Noise							
Mean	1.56	1.55	1.63	1.51	1.53	0.830	NA
SD	0.95	0.99	0.94	0.86	0.89		
Irregularity							
Mean	3.18	3.42	3.57	3.08	3.17	0.428	NA
SD	1.35	1.63	1.54	0.90	1.12		

*Statistical significance ($p < 0.05$)

Caption: DG = group of dysphonic individuals; m0 = pre-exercise; m1 = after 1 minute; m3 = after 3 minutes; m5 = after 5 minutes; m7 = after 7 minutes; TMF = maximum phonation time; F_0 = fundamental frequency; GNE = glottal to noise excitation; SD = standard deviation; NA = analysis not applicable

Table 4. Average and standard deviation of acoustic parameters of VHG according to each moment (m0, m1, m3, m5 e m7) and comparison among them

Parameters	m0	m1	m3	m5	m7	Anova (P value)	Tukey's Multiple comparison
MPT (s)							
Mean	13.9	15.2	15.6	15.9	16.1	0.049*	m0 < m1 = m3 = m5 = m7
SD	2.5	4.1	3.5	4.1	3.3		
F_0 (Hz)							
Mean	195.5	187.9	187.4	189.1	188.6	0.247	NA
SD	15.9	12.8	15.4	17.0	17.7		
Variability of F_0 (Hz)							
Mean	7.3	6.7	6.3	7.4	7.0	0.742	NA
SD	4.1	3.4	2.3	3.2	4.2		
Variability of F_0 (semitones)							
Mean	0.70	0.77	0.57	0.83	0.60	0.234	NA
SD	0.53	0.50	0.50	0.46	0.56		
Jitter (%)							
Mean	0.27	0.18	0.20	0.18	0.16	0.457	NA
SD	0.49	0.11	0.11	0.13	0.10		
Shimmer (%)							
Mean	2.19	1.96	1.90	1.98	1.91	0.796	NA
SD	1.33	0.88	0.76	1.06	0.97		
GNE							
Mean	0.77	0.78	0.78	0.78	0.78	1.000	NA
SD	0.16	0.16	0.15	0.15	0.15		
Noise							
Mean	1.17	1.16	1.11	1.13	1.15	0.998	NA
SD	0.66	0.69	0.64	0.63	0.64		
Irregularity							
Mean	2.68	2.52	2.44	2.40	2.37	0.452	NA
SD	0.77	0.68	0.60	0.68	0.74		

*Statistical significance ($p < 0.05$)
Caption: VHG = group of vocally healthy individuals; m0 = pre-exercise; m1 = after 1 minute; m3 = after 3 minutes; m5 = after 5 minutes; m7 = after 7 minutes; TMF = maximum phonation time; F_0 = fundamental frequency; GNE = glottal to noise excitation; SD = standard deviation; NA = analysis not applicable

DISCUSSION

Vocal techniques are important tools for therapists in rehabilitation and vocal training work[2,3], thus the need to obtain more and more data about prescription of these therapies, something that has been gaining importance in the literature over the last few years[8,9].

Resonance tube exercises, which use tubes and straws as artificial extensors of the vocal tract[15], have been recognized as beneficial for vocal rehabilitation and training for more than a century, according to the clinical observation of authors who have shared their experiences in textbooks since those times. These exercises, despite their long-standing tradition in Europe[12], have gained worldwide popularity only in the last two decades and, at the same time, have been subjected to studies aimed at understanding their physical principles and vocal effects, but there are still few contributions in this regard[15,22-24].

The initial objective of this study was to verify the effect of high-resistance straw exercise dosage in dysphonic as well as vocally healthy individuals. However, respecting the literature's suggestions of directing intervention to specific groups and considering the time available to carry out this study, only women with chronic behavioral dysphonia and vocally healthy women were included in the sample, since they are populations for which the exercise studied is indicated[15].

It is common for patients with behavioral dysphonia to seek professional help when dysphonia is already in place and of moderate degree - when vocal alteration begins to have more serious impacts on the daily life of the individual. This is the case of the participants that composed the DG of this study, who presented average general vocal deviation degree corresponding to a moderate level (mean = 56.2 and SD = 19.2), according to the auditory-perceptual analysis of the first vocal record (m0). On the other hand, the VHG presented average general vocal deviation degree corresponding to the range that represents normal variability (up to 35.5 mm, mean = 25.9 and SD = 9.0).

In addition, patients with vocal complaints who seek professional help report a greater amount of vocal signs and symptoms (6.3, on average) than individuals without vocal complaints (1.3, on average)[27]. This data was confirmed in the present study, which found means of 6.9 (SD = 2.3) signs and symptoms for the DG and of 0.9 (SD = 0.8) for the VHG.

The self-rating of the effort is an information path considered for many years in sports medicine, since it contributes to the knowledge of muscular demand in face of a certain exercise load, serving as an estimate of the subjective state of fatigue. This helps professionals to adjust the frequency, duration and intensity of training[8]. In vocal rehabilitation, this aspect has not received due attention, being restricted to a few comments in specialized textbooks[16].

The concept of subjective perception of effort (SPE) originated from a pilot study conducted over five decades ago, in which the authors verified that physiological tension increases in line with exercise intensity and perception of effort[26,28]. Therefore, if an individual indicates a score of 4 on a scale from 0 to 10, or 40 on a scale from 0 to 100, the muscle work performed at that moment is expected to be 40% of maximum force production[26,29].

From the hypothesis raised at that time, several scales were developed and improved, including the determination of verbal anchors that provide meaning to the scores. As there are no studies on the use of these scales in the Voice field, what each score represents for the phonatory system is unknown. For this reason, we chose to use the 100mm VAS in this study, with verbal anchors only at 0 (no effort) and 100 (maximum effort).

For example, in the application of the RASO scale[29] in exercises with weight (from 0 to 10), a physical effort of 0% to 10% represents extremely mild intensity; an effort from 20% to 30% represents very mild intensity; between 40% and 50%, mild intensity; between 60% and 70%, somewhat heavy; 80%, heavy; 90%, very heavy; and 100%, extremely heavy. Thus, the effort to speak for the VHG (between 7% and 10%) would be classified as "extremely mild" throughout the 7 minutes of exercise, and effort in the exercise (around 20%) would be "very mild". This does not seem unusual, since this group is composed of vocally healthy women, with no complaints of phonatory effort. However, for the DG, both speech and exercise effort would be classified as "mild" (recorded at around 40% and 50% at all times, with the exception of the effort in s7, which was of 60.3 - "somewhat heavy"). This does not seem consistent with the reaction of the volunteers of this study, who even verbalized the difficulty they had to perform the exercise for the full period requested. Therefore, we do not consider it prudent to use SPE scales developed for physical training in Voice for as long as detailed research is not performed in order to clarify what each score represents for the voice exercises.

On the other hand, the comparison of this study's results with the verbal anchors of the CR10 scale (category-ratio 10) of BORG[26] (from 0 to 10) - more general scale of intensity used for most subjective magnitudes, particularly in scientific studies for assessment of the intensity of training through SPE - is quite interesting. For this scale, an effort equal to 5% represents an extremely mild intensity; 10%, very mild; 20%, mild; 30%, moderate; 40%, not very intense; 50%, intense; 60%, intense to very intense; 70% and 80%, very intense; 90%, extremely intense; and 100%, maximum. Therefore, for the VHG, the speech and exercise effort could be translated as "very mild" and "mild", respectively, from the beginning to the end of the test. This is acceptable for the same reason presented for comparison with the previous scale. For the DG, statistically significant results for increase or reduction of effort are accompanied by changes in the verbal designations of anchors: the effort to speak that begins at 50%, thus "intense" (which justifies the commonly observed vocal fatigue complaint in this population), reduced to 37% after 1 and 3 minutes of exercise, becoming "not very intense", and increases again after 5 and 7 minutes, returning to the initial intensity (51% = "intense"). The effort in the exercise at the end of the first minute is 37% ("not very intense"), it increases at the end of the 3rd and 5th minutes (around 50% = "intense") and increases even more at the end of the 7th Minute, ending at 60% ("intense" to "very intense"). These verbal anchors are more consistent with the observation of the participants' reaction, which suggests that the use of this scale in the Voice field is acceptable. However, this is only a hypothesis raised in this study, which needs to be confirmed in future studies.

Upon analyzing the parallel evolution of speech and exercise effort values (Tables 1 and 2), it is possible to verify that for the VHG both maintain the same intensity from beginning to end, as mentioned above. With regard to the DG, as the speech effort decreases, the exercise effort increases, and this occurs until the 3rd minute of exercise, when the speech effort worsens again. The results are clear: probably, at the end of the first minute of exercise, the DG already perceived the need to apply greater effort when asked to sonorize in a high-resistance straw with compromised functional capacity. When the exercise is interrupted and the participant is instructed to produce a sustained vowel and an articulated speech excerpt, this time without semi-occlusion of the vocal tract, the physiological adjustment for the previous exercise is no longer necessary. For this reason, the participants have the sensation of reduced effort in speech. This occurs in many other structures of the body when exposed to different loads of effort in a short period of time, following the same principle, for instance, of swimming with and then without a T-shirt, shooting basketball balls and then training lifting with volleyballs, or training kicks, in soccer and martial arts, with shin pads and then without them. For all of these types of physical training, when muscle overload is relieved, the feeling is that the activity is performed more easily. When the body adapts itself to an activity at a certain level of overload with subsequent removal, it needs time to make a new adjustment to the new need[8]. With continued exercise, the phonatory system continued to be exposed to additional load typical of the exercise studied, and the fact that the effort to speak was not consistently lower, having worsened again, suggests that this exercise causes a certain level of fatigue in this population after 5 minutes.

Regarding the acoustic parameters, it is known that the measures of MPT can improve with training in the task, which may have influenced the initial improvement of this parameter in both groups. However, for the DG, both the MPT and the other vocal parameters that improved between 1 and 5 minutes (effort to speak and variability of F_0 - Tables 1 and 3) worsened with continued exercise. This fact, associated with the progressive increase in effort to perform the exercise (Table 2), indicates that 7 minutes of exercise for this population represents a decrease in phonatory capacity and a perception of overload in the system, potential characteristics of a state of fatigue. One thing this study does not clarify is to what extent this overload is necessary to produce beneficial effects in the long term, as stipulated by the overload principle, or to what extent it can be harmful to the phonatory system, for being excessive.

Based on the measurement of fatigue, we seek to understand the degree of muscle wearing out, and that is why it is important to quantify it. However, there is no direct method for quantitative evaluation of fatigue status. All of the methods used to this day measure specific manifestations that can only be evaluated as indicators of fatigue.

Laryngeal muscles are naturally resistant to fatigue because of the importance and need for communication in the human race, but it is recommended that individuals who use their voice for long hours, even if vocally healthy, undergo vocal resistance training[16]. However, for this population, with the current knowledge available in the literature, it is not possible to determine a safe limit of duration for the series capable of generating a beneficial vocal overload necessary for the evolution of training. In this study, it was verified that, for the high-resistance straw phonation exercise, 7 minutes do not represent a decrease in the phonatory capacity that indicates vocal fatigue for vocally healthy women. Therefore, one may limit the duration of this exercise to this time.

The results found in this study after 1 minute of exercise can be compared with the findings of two scientific studies performed with the same technique and duration[1,25]. A study[25] carried out with women with no vocal complaints verified improvement in vocal quality of articulated speech excerpts (analysis not performed in the current study), as well as positive effects on the individuals' self-rating and reduction of fundamental frequency, which did not occur in this study for the vocally healthy population (VHG).

On the other hand, another study[1], performed with dysphonic and non-dysphonic individuals, more discrete results were observed with positive effects only in the self-rating of dysphonic individuals, who reported easier voicing. This result can be compared to the reduction in phonatory effort verified in the present study for the dysphonic population (DG) after 1 minute of exercise. No other parameter analyzed changed due to the exercise in either study[1,25]. Some parameters of this study also did not change with the time of exercise in both groups (DG and VHG): F_0 and its variability in semitones, jitter, shimmer, GNE, noise, and irregularity.

The time of 1 minute for performing an exercise may not be sufficient to generate the desired vocal modifications, which has already been mentioned in previous studies[1,25]. However, in this study we could verify that 7 minutes also did not contribute to changes in other vocal parameters, especially for the VHG, probably because they are individuals without voice problems, whose reference values (m0) are already within normal range, with low probability of improvement with the exercise.

We suggest that more studies like this be carried out with the same exercise, however with frequency variation or other voice exercises. In addition, this study is a case series, whose main objective is to raise hypotheses.

Therefore, we also suggest that studies, particularly experimental ones, be carried out in order to clarify these findings, such as the matter of the level of overload of voice exercises and their long-term effects for both the dysphonic and vocally healthy population. Speech therapists who work with vocal rehabilitation and improvement need knowledge to guide them in the construction of training programs.

CONCLUSIONS

The impact of the high-resistance straw exercise was different between dysphonic and non-dysphonic women, and the impact on the parameters analyzed was different throughout the 7 minutes of exercise.

The exercise studied generated positive vocal changes in women with behavioral dysphonia until the 5th minute, with a predominance of positive responses in the 3rd minute: less effort to speak, increased MPT, and reduced F_0 variability; these vocal parameters worsened with continued exercise. This fact associated with the progressive increase of effort to perform the exercise indicates a probable overload of the phonatory system.

Vocally healthy women presented an increase in MPT after 1 minute of exercise; the remaining parameters analyzed in this study did not change over time, probably because they were voices without alterations; 7 minutes does not seem to cause overload for this population.

The parameters F_0 and its variability in semitones, jitter, shimmer, GNE, noise, and irregularity did not change according to the time of exercise in any of the groups.

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Author contributions

We hereby declare that all of the authors have taken sufficient part in the production of this manuscript to make public their accountability for its content. SMP was responsible for the research design, data collection and analysis, writing and proofreading of the paper; MB was responsible for the research design, data analysis, and final review of the paper.