The Effects of Amplification on Vocal Dose in Teachers with Dysphonia

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Summary: Purpose. The purpose of this study was to determine if voice amplification influenced vocal dose in female teachers with dysphonia.

Material and Methods. This was an experimental study with comparative intrasubjects in which 15 individuals were compared in two different moments: condition 1 (C1) without voice amplification and condition 2 (C2) with voice amplification. All of them were female, kindergarten and elementary school teachers who presented organic or functional dysphonia. The search was carried out at the school where the teachers work. The professional voice use was considered the teachers' activity for a continuous period of two classes (average recording time of 96 minutes, with no difference in time between C1 and C2). To measure the dose we used the vocal dosimeter composed of a microphone, an accelerometer fixed to the neck, and a portable unit that stores the vocal data. The phonation data (intensity, fundamental frequency, phonation percentage, cycle dose, and distance dose) were analyzed by the equipment software (*VoxLog*).

Results. The use of vocal amplification in teachers promotes a reduction of the fundamental frequency (295.6–267.7 Hz), the voice intensity (96.2–93.3 dB sound pressure level), the cycle doses (489.4–345.2 thousand cycles per second), and distance doses (3,800–2,300 m).

Conclusion. The vocal amplification allows the teacher to maintain the same phonation time (phonation percentage) but decreases the number of vocal fold oscillations (cycle dose) and the total distance traveled by the vocal fold tissue during phonation (distance dose), reducing the exposure of the vocal folds to voice trauma.

Key Words: Voice–Teacher–Vocal dose–Dysphonia–Voice dosimetry.

INTRODUCTION

Teachers use their voices as the primary tool of their trade, and they have intense vocal demands[1] and are vulnerable to developing dysphonia.[2–4] Significant background noise in the classrooms is one of the main factors associated with the development of voice disorders in teachers.[5] Teachers are likely to develop phonotrauma in noisy environments, and prolonged voice use in these conditions can generate vocal fold lesions, yielding progressively worsening hoarseness over time.[3] This phenomenon is likely related to increased vocal intensity causing an increase in fundamental frequency, which can lead to hyperfunctional vocal behaviors.[6]

Voice symptoms commonly described in teachers include fatigue, discomfort, strain, hoarseness, breathiness, changes in vocal quality, and dry throat. These symptoms can cause missed workdays, changes in lesson planning, reduced teaching activities, frustration, concerns about future employment, prolonged rehabilitation, and at worst, a change of professions.[1–3] Furthermore, altered speech intelligibility may negatively impact student performance.[7]

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Vocal dose was described as a group of measurements that assess the degree of exposure of vocal fold tissue to vibration over time.[8] The vocal dosimeter is a portable device used to obtain voice use-related data during normal daily activities. Vocal dosimeters quantify the intensity, frequency, and duration of vocal activity in terms of sound pressure level (SPL), fundamental frequency, and time of voice use. These data can be used to determine the complex relationship between voice use, vocal fatigue, and vocal recovery time,[9] correlating vocal use with vocal problems or identifying phonotraumatic behavior.[4]

To measure the vibratory exposure of vocal fold tissue during speech, time dose, cycle dose, and distance dose are commonly employed variables. Time dose or percentage of phonation quantifies the total time of vocal fold vibration during speech.[8] Cycle dose quantifies the number of vocal fold oscillations during a specified period.[8] Distance dose is the total distance traveled by vocal fold tissue during vibration.[8] Occupational standards outlining safe levels of tissue vibration for body parts such as ears and hands have been established,[10] yet little is known regarding safe levels of tissue vibration of vocal folds.[10]

Voice amplification has been described to decrease vocal dose.[11,12] Recent research described reduced vocal dose in seven music teachers[11] and two elementary school teachers[12] when using amplification while teaching. The literature also includes clinical studies suggesting that amplification protects teachers from vocal strain during prolonged vocal use, reducing vocal fatigue and facilitating healthier occupational voice use[6,13] in addition to promoting improved self-perception of dysphonia[13] as well as improved student comprehension and concentration.[14]

Most teachers tend to maintain their voice at 10–15 dB above environmental noise.[6] With amplification, the vocal load imposed on the vocal fold tissue is expected to be reduced. By reducing intensity and thereby vibration dose, the degree of injury to vocal fold tissue caused by the collision force is likely decreased.[6,15] As such, a recent clinical study suggested that amplification was associated with improved self-perception of voice in teachers.[6]

Given the high prevalence of voice disorders in teachers and the fact that the presence of environmental noise in classrooms is the main factor associated with dysphonia, the present research was designed to answer the following question: Does the vocal amplification of dysphonic teachers have an impact on vocal dose? The hypothesis is that the use of vocal amplification in dysphonic teachers decreases vocal dose and may be a protective tool for vocal disorders.

In the current study, we sought to determine if voice amplification influenced vocal dose in female teachers with dysphonia.

MATERIALS AND METHODS

The current study was approved by the Ethics in Research Committee of the Institution with the number 47212615.1.0000.5149. A cross-sectional study was conducted based on the evaluation of teachers with dysphonia referred for voice therapy in a Speech-Language Pathology Clinic (Hospital das Clínicas/UFMG) from October 2015 to September 2016.

Seventeen teachers were invited to participate in the study, and 15 teachers from the kindergarten and elementary school of Municipal and State Schools of Belo Horizonte, Brazil, participated in the current study. All subjects were female between 33 and 44 years (average 38.6 years), and the mean duration of their teaching career was 11.8 years (standard deviation = 5.03 years). Inclusion criteria were dysphonia defined by speech-language pathology and otorhinolaryngology assessment. Exclusion criteria were pregnancy, menstrual period, being a smoker, and/or auditory or pulmonary complaints or upper-airway infection.

For otorhinolaryngology assessment, all subjects underwent videolaryngoscopy; the following findings were identified: vocal fold nodules (66.7%), glottal chink (13.3%), edema (13.3%), and vocal fold cyst (6.7%). For speech-language pathology assessment, all subjects completed the Voice Symptom Scale protocol validated in Brazilian Portuguese.[16] The results ranged from 17 to 77 points (average of 37.5). In this scale, the higher score correlates with a voice problem.[16,17] A score of 16 or greater has been shown to be indicative of significant dysphonia.[17] The auditory perceptual evaluation was performed for two speech language pathologists with experience in voice clinic using the GRBAS scale. Dysphonia was determined by the presence of altered vocal quality, with deviations varying from mild to moderate. All participants started voice therapy after collecting survey data.

In order to determine the number of teachers required for adequate statistical power, the free program *G.Power 3.1* (Düsseldorf University, Germany)[18] was used. Sample size was based on a recent study by Rabelo et al.[19] This study compared cycle dose in women in various acoustic conditions, with or without noise. Fifteen teachers were necessary in each group, considering the Wilcoxon test for paired samples with a power of 95% and an alpha level of 0.05 (5%).

Vocal dose was quantified at the school where the participants taught. Each teacher was evaluated in two different conditions: C1 (without voice amplification) and C2 (with amplification). All teachers did not previously use vocal amplification and were instructed by the researchers on how to use the equipment.

The two recording conditions (C1 and C2) and vocal dose were kept consistent across activities with the same group, in the same classroom, on the same day of the week, with a minimum interval between sessions of 1 and maximum of 6 weeks (average 1.9 weeks). Recording time varied from 70 to 120 minutes with an average of 96 minutes. No statistically significant ($P = 0.86$) differences were observed with regard to the time of C1 (average = 96.7) and C2 (average = 96.3).

In order to obtain acoustic and vocal dose measurements, the *VoxLog* (Sonvox model 3.1; Biotech Umeå, Umeå, Sweden) dosimeter was employed. This system includes a microphone, an accelerometer, and a portable data storage unit. The accelerometer and the microphone were placed on the neck region near the thyroid cartilage. Phonation data were stored in the portable unit and analyzed with the manufacturer's software. The following parameters were assessed:

1. Vocal intensity: the amount of sound energy produced. Intensity is related to the amplitude of vocal fold oscillation and is measured in decibels of SPL.[8]
2. Fundamental frequency (F_O): the rate at which a waveform is repeated per unit time and is measured in hertz.[20]
3. Percentage of phonation: the relative time spent phonating related to a fixed interval and is measured as a percentage.[12]

$$\frac{\text{Time of phonation} \times 100}{\text{Time of recording}} = \%$$

4. Cycle dose: the number of vocal fold oscillations during a fixed interval. It is calculated based on the duration of phonation and the average of the fundamental frequency. The value, in thousands of cycles, is defined by[20,21]

$$\mathrm{D_c} = \int_0^{tp} \mathrm{k_v} FO \mathrm{dt},$$

where t_p is the time of performance, that is, the time during which the individual used his voice, speaking or singing, F_O refers to the fundamental frequency of the vocal folds in hertz, and k_v is the function defined by[20]

$$k_v = \begin{cases} 1(\textit{for voice emitting sound}) \\ 0(\textit{for voice not being used}) \end{cases}$$

As the number of cycles is high (hundreds per second), this variable was adapted to be measured in units of thousands of cycles (D_c/1,000).[20]

5. Distance dose: the total distance traveled by the vocal fold tissue during phonation. This variable depends not only on the total time of phonation and fundamental frequency but also on the amplitude of the vibration of the vocal

folds and therefore, vocal intensity (decibels). This dose, in meters, is defined by[20,21]

$$D_d = 4\int_0^{tp} k_v AFO\,dt,$$

in which F_O is the fundamental frequency of the vocal folds (hertz) and A is the amplitude of the vibration of the vocal folds at the top and the base.

The manufacturer's software performed the calculations of all parameters, except distance dose, which was measured as previously described.[20] The values of distance dose were calculated using the algorithm developed by Svec et al.[20] The value of A can be estimated using the empirical rules derived in

$$A = 0{,}05\, L_o\left[(P_L - P_{th}) / P_{th}\right]^{1/2}\, m,$$

where L_o is the reference of vocal fold length (0.016 m for men and 0.01 m for women), P_L is the pulmonary pressure, and P_{th} is the limit of phonation pressure. The empirical rule for P_{th} is[20]

$$P_{th} = 0.14 + 0.06\,(F_O / F_{ON})^2\, kPa,$$

where F_O is the fundamental frequency and F_{ON} is the nominal fundamental frequency (120 Hz for men and 190 Hz for women). The empirical rule for pulmonary pressure is derived from the measurement of the SPL 50 cm from the mouth and is described as[20]

$$P_L = P_{th} + 10^{(\mathrm{NPS}-78{,}5)/27{,}3}\, kPa.$$

In C2, the teachers used the portable vocal amplifier (BOAS® Model BQ-810, China) during an entire class period. To control background noise, a digital SPL with data-logger Instrutherm model DEC-490 (Instrutherm, Brazil) with a type 2 microphone was employed. Background noise levels while teaching in conditions C1 and C2 were measured in the octave bands that included the frequencies from 63 Hz to 8,000 Hz, with furnished classrooms and school activities occurring normally in adjacent classrooms. The sound pressure meter was placed near the teacher, 1.2 m from the ground (ANSI S12.60, 2010). The weighting curve A was used, and the equipment employed the fast mode.

The software analyzed values each second by the sound pressure meter and calculated the average intensity of noise during the class interval. These values were 70.5 dB SPL in C1 and 67.1 dB SPL in C2, and they remained stable in the two recording conditions (C1 and C2).

A database was generated using the *Statistical Package for the Social Sciences* version 19.0 (SPSS Inc., Chicago USA). Preliminary statistical analysis employed the Kolmogorov-Smirnov test for normality. The Student paired *t* test was used to compare the parameters with normal distribution in the two conditions (C1 [without voice amplification] and C2 [with amplification]). For variables without normal distribution, "percentage of phonation" with and without amplification, and "vocal intensity" with amplification, the Wilcoxon test was employed. The alpha level was 0.05 (5%).

RESULTS

A summary of the data from the 15 teachers, with and without voice amplification, is presented Table 1. Amplification resulted

TABLE 1.
Results of the Phonation Data of the Teachers, With and Without the Use of a Vocal Amplifier

		F_O (Hz)	Intensity (dB SPL)	Percentage of Phonation (%)	Cycle Dose (Thousands Cycles/Second)	Distance Dose (M)
Without Vocal Amplification	Average	295.6	96.2	27.1	489.4	3800
	Standard deviation	46.47	3.39	16.85	175.28	1310
	Median	279.9	96.2	23.9	516	4500
	Minimum value	237.8	91.2	8.1	121	900
	Maximum value	415.6	102.4	81.7	784	5200
With Vocal Amplification	Average	267.7	93.4	25.7	345.2	2300
	Standard deviation	33.34	6.28	15.96	115.29	820
	Median	267.6	93.3	24.2	339	2400
	Minimum value	211.5	73.3	11.4	185	1300
	Maximum value	353.2	98.7	79.7	546	4200
	P value	0.01*	0.02†	0.69†	0.011*	0.003*

* Student's *t* test.
† Wilcoxon test.

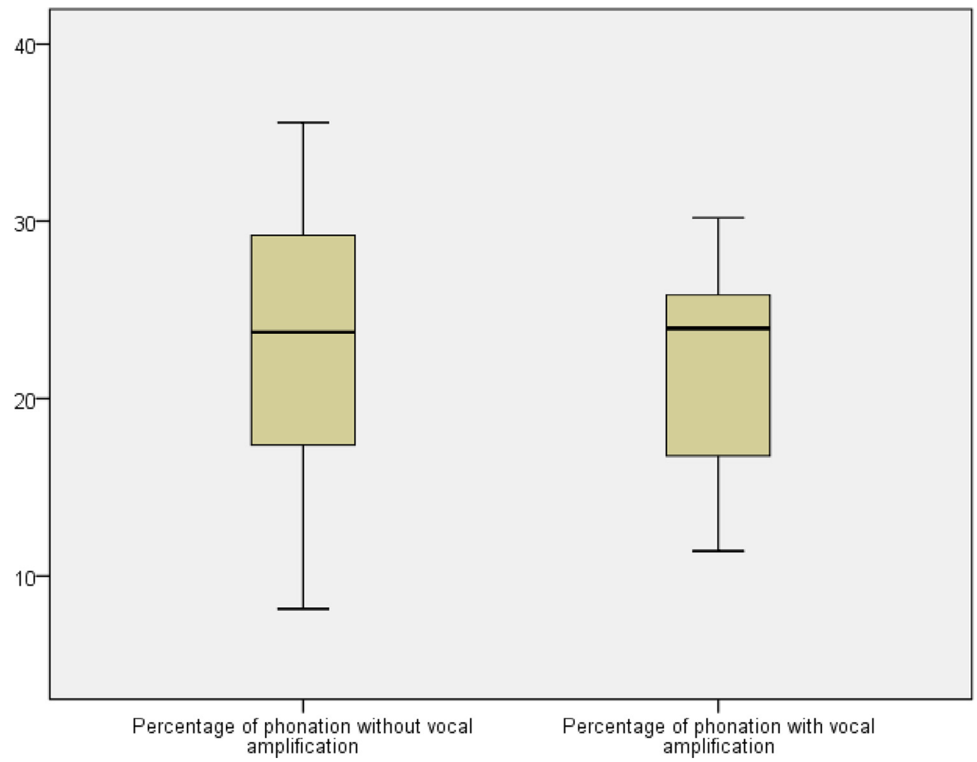

FIGURE 1. Percentage of phonation with and without vocal amplification.

in decreased F_O as well as reduced intensity and cycle and distance doses.

Figures 1–3 illustrate the percentage of phonation and the cycle and distance doses with and without amplification, respectively.

DISCUSSION

Dysphonic teachers who use voice amplification while teaching do not reduce the duration of speech during classes but expose the tissue to decreased vocal fold vibratory load with decreased

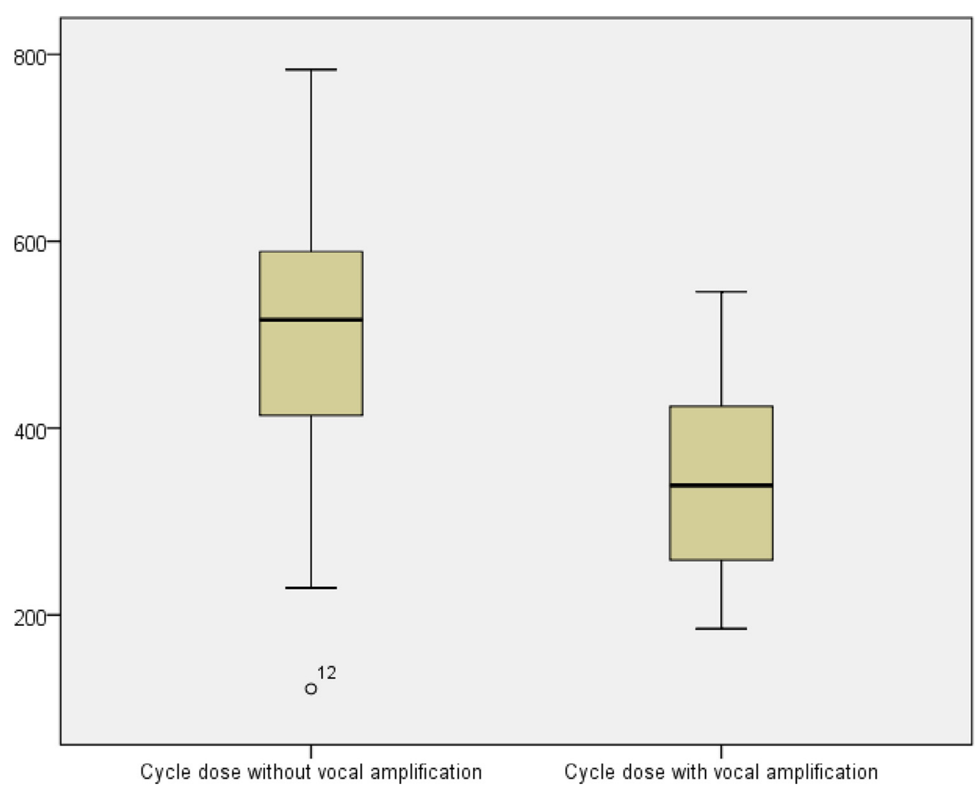

FIGURE 2. Cycle dose with and without vocal amplification.

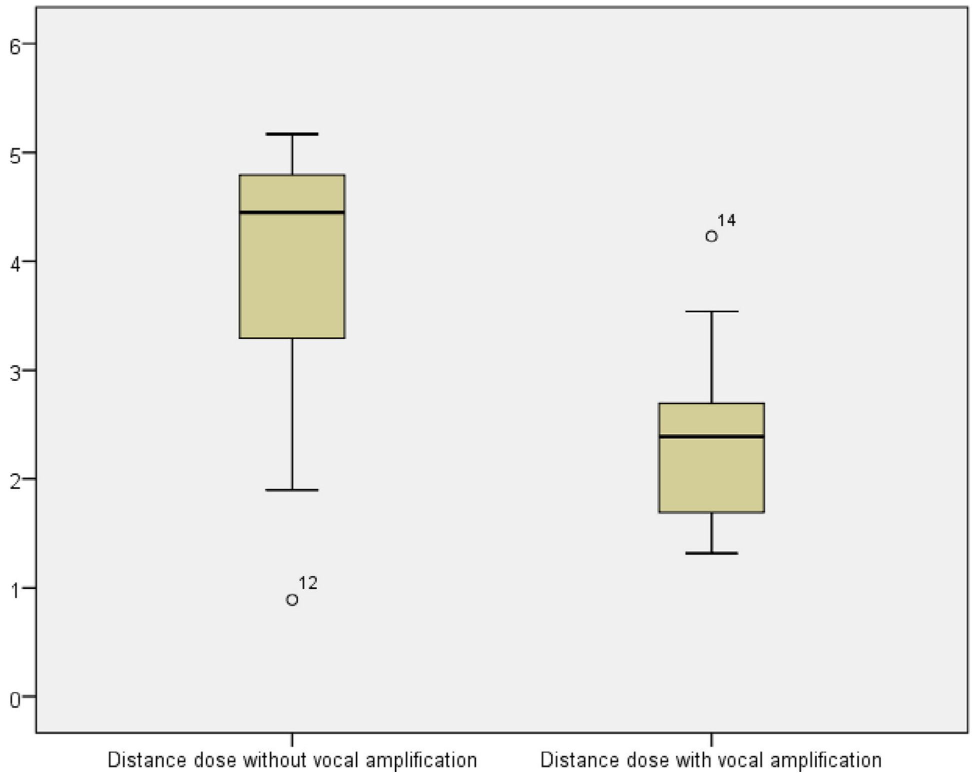

FIGURE 3. Distance dose with and without vocal amplification.

cycle and distance doses. In addition, amplification resulted in decreased vocal intensity and lower pitched voice, consistent with more natural voice use.

With regard to experimental design, select variables were controlled; the literature highlights that dysphonia,[4,22] background noise,[23] and didactic activities[8,24] can influence vocal dose. A pilot study comparing dysphonic and control teachers observed increased phonation time and cycle dose in teachers with dysphonia, which suggested that the vocal fold tissue was exposed to increased vibratory load.[22] Teachers were also likely to present with increased vocal load due to altered intelligibility as a result of dysphonia.[7,22] Only dysphonic teachers were included in the present study due to the increased vocal dose.

Recent data suggested[19] that noise contributes to the decreased comprehension of an oral message by students, resulting in increased vocal dose in teachers. The current study corroborated previous data that associated increased vocal dose with background noise.[25] The higher the noise, the higher the intensity of voice use among teachers, an involuntary reaction to the presence of noise referred to as the Lombard effect.[25] This finding suggested the need to control the noise in the two recording conditions in the current study, ensuring consistency with and without amplification.

Another variable that was controlled was the didactic content presented by the teachers during both recording conditions. Both classes were taught using the same strategies, as didactic activities that require increased prosodic variation such as singing and character voices are associated with increased vocal dose.[8,24] Furthermore, activities requiring little vocal use, such as test administration or group work, were not compared with lectures given the marked differences in vocal load.

The present study concurred with findings from two prior studies that compared vocal dose with and without voice amplification.[2,11] A recent study found significantly decreased intensity, cycle dose, and distance dose when singing teachers employed amplification.[11] In addition, a recent case study analyzed the vocal dose of two elementary school teachers, and amplification resulted in decreased distance dose.[2] Clinical studies of teachers with and without a microphone corroborate with these data; teachers presented with decreased vocal fatigue[6] and improved voice quality,[26,27] in addition to easier voice production and decreased resistance of voice, as well as an improved comprehension and concentration in the students, with voice amplification.[14]

The results of the present study revealed that teachers increased fundamental frequency and intensity without vocal amplification. Most likely, this finding was related to the phenomena that increased intensity is correlated to increased frequency. Teachers are likely to frequently alter intensity, and therefore, fundamental frequency.[6,28] Increased fundamental frequency was recently described as the result of increased muscle activity, likely in response to the vocal load during the workday.[29,30] Most teachers tend to maintain a vocal intensity of approximately 10–15 dB above background levels, which is above the intensity of a normal conversation.[6] Voice amplification favors voice production at decreased intensities, with less vocal effort. Cumulatively, these data confirm that amplification is critical to the maintenance of vocal health among teachers.[13]

The percentage of phonation with and without amplification was not significantly different; amplification did not influence the quantity of speech by teachers. This finding corroborated with a recent study of two elementary school teachers; amplification had no effect on time dose.[2] As for the study with music teachers, phonation time decreased with amplification, which is likely associated with favorable auditory feedback yielding improved control of vocal intensity and due to the fact that the vocal dose analysis was related to the percentage of phonation when singing[11] and not to speech while teaching.

In previous studies, altered percentage of phonation was reported in some situations. In teaching, the time dose was higher than in the vocal loading tests.[31] Time dose was also higher in professional environments compared with social environments.[23] In addition, time dose was higher during the individual rehearsal and the teaching.[32] Interestingly, music teachers presented a higher percentage of phonation when compared with elementary school teachers while teaching.[24] Therefore, these data highlight that time dose, defined as the amount of total time of vocal fold vibration during speech,[20,21] is higher in activities of vocal overload[31] and in professional voice use,[23] including singing[32] and teaching.[24] For dysphonic teachers, the results of this research suggest that the total time of speech while teaching is not affected by amplification.

Voice amplification reduced both cycle and distance dose, resulting in decreased quantity of vocal fold vibration. These data suggest that despite the fact that amplification while teaching did not decrease the total speaking time in dysphonic teachers, it decreased the amount of vocal fold oscillations[20,21] (cycle dose) and the total distance traveled by the vocal fold tissue during phonation[20] (distance dose). These results suggest that amplification reduced the quantity of vocal fold vibration, resulting in reduced impact and decreased damage to the vocal folds as a result of collision force.[6,10,11,13–15] Amplification appeared to protect the voice of the teachers with dysphonia without necessarily restricting the amount of vocal use.[15] Particularly in teachers with dysphonia, amplification is an effective and low-cost intervention to potentially decrease the damage associated with the vocal load while teaching and is a critical component of vocal health promotion.[6]

Within the field of speech therapy, voice has been an area of focus with regard to maintaining and promoting health. A more broad analysis is required with regard to the vocal health of teachers, changing the emphasis from disease/treatment to health/promotion.[33] The literature suggests the need for changes and adaptations to working conditions, as well as the diminishing barriers to vocal health in the workplace.[34] A recent study analyzed Brazilian laws regarding the vocal health of teachers and found that the majority of documents did not imply any implicit rights of teachers, with the exception of the treatment of dysphonia. Furthermore, incipient and superficial text was noted with regard to voice care, with rare exceptions. These findings suggest that voice care in teachers has not evolved to be a federal concern, which is further exemplified by the fact that voice disorders are not considered an occupational risk for teachers.[35] Public policies based on worker health and the identification of risk factors underlying injuries to teachers are essential to promote improved working environments and processes to improve quality of life with regard to voice disorders.[36]

These results can, along with emerging data regarding the high prevalence of vocal disease and consequent absenteeism,[37] provide a basis for legislation to ensure professional vocal health and incentives for the use of the voice amplification in teachers. In addition, investigation is needed to identify healthy limits of vocal dose to ensure vocal health in this high-risk population.

CONCLUSION

Voice amplification while teaching in dysphonic teachers resulted in reduced intensity and lowered pitched voice. Amplification allowed teachers to maintain the same phonation time (phonation percentage) but reduced the number of vocal fold oscillations (cycle dose) and the total distance traveled by the vocal folds during phonation (distance dose), exposing the vocal folds less to phonotrauma and consequently promoting vocal health.

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