The Influence of Noise on the Vocal Dose in Women

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Summary: Objective. The objective of this study was to evaluate if noise interferes with the vocal dose in women without vocal complaints.

Study design. This is an experimental and comparative study.

Methods. Data were collected on 27 women between 22 and 50 years of age without vocal complaints in a university classroom. Speech-language pathology evaluation was performed employing auditory-perceptual analysis and a vocal symptom questionnaire. The acoustics of the classroom were evaluated via both observation of the characteristics of the room and the quantification of background noise and reverberation time. Two distinctive acoustic conditions were created for evaluations: condition 1, a room without acoustic treatment and without noise reproduction, and condition 2, a room without acoustic treatment with noise reproduction. Each participant was evaluated individually in both acoustic conditions. To obtain vocal dose data, a vocal dosimeter was used. Subjects were asked to perform two 10-minute readings, one in each acoustic condition. The order of conditions was randomized between subjects. Subjects were instructed to complete the reading tasks at the vocal intensity deemed appropriate to be heard by a listener in the back of the room. *t* Tests and the Wilcoxon test were employed to compare parameters across subjects and conditions.

Results. Fundamental frequency, vocal intensity, percentage of phonation, and cycle dose significantly increased in the background noise condition.

Conclusion. A positive relation between vocal dose and the presence of excessive noise in the environment was observed.

Key Words: Voice–Teacher–Dysphonia–Voice disorder–Noise

INTRODUCTION

The objective of the current study was to evaluate whether noise affects vocal dose in women without vocal complaints. The World Health Organization recently warned that environmental noise may result in altered human development, as well as decreased general health of the individual. The observed effects range from fatigue to nervousness, stress, anxiety, altered memory, and irritability.[1] The noise in classrooms is widely discussed because of the potential health risks and the putative impediments to school activities. Recent studies suggest that favorable acoustic conditions in the classroom likely enhance learning[2,3] and that noise likely compromises learning.[4]

Background noise in the classroom, beyond competing with the voice of the teacher, can disturb or even prevent oral communication and can have deleterious physical, emotional, and educational effects[5,6]; that is, noise can yield altered hearing or tinnitus thresholds, as well as increased effort to concentrate and comprehend the spoken message and vocal effort to increase voice intensity.[6] A recent study suggested that the increase in vocal intensity in teachers correlated with high levels of noise.[7] In such situations, the Lombard effect occurs, which is an involuntary vocal response to background noise.[8]

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The various daily demands associated with environmental factors, both health-related and organizational, can cause increased vocal intensity in professional environments, which, in association with inadequate working conditions and lack of vocal knowledge and insight, can lead to damage to the individual.[9,10] The presence of background noise is defined in the literature as one of the main factors associated with dysphonia in teachers.[11] The Brazilian legislation, by the Regulatory Norm number 17, indicated an adequate classroom environment to have a noise level below 65 dB (A). In addition, a recent American study suggested restructuring of acoustic conditions in classrooms based on a background noise threshold of up to 70 dB (A).[12]

The term *vocal dose* is used to define the exposure of vocal fold tissue to vibration and allows for the quantification of voice use in a set period of time. Rapid accelerations or decelerations or even contact forces between the vocal folds traumatize your surface tissues. This exposure can be quantified by dose.[13,14] The literature highlights that classroom noise increases vocal dose, linking the potentially damaging effects of noise on teachers' voices.[15]

Although the risks of noise exposure for professionals are known, no current policies are in place to prevent these issues.[16] Further studies regarding vocal dose are necessary to determine, for instance, unhealthy vocal doses based on different acoustic conditions.[16] To develop occupational health in professions that demand voice use, it is necessary to analyze the correlation between environmental factors in the workplace and vocal dose, particularly in voice professionals.[17]

METHODS

The current study was approved by the Municipal Secretary of Education of the city of Belo Horizonte and by the Ethics and Research Committee of the institution under the number 352/2012. All the individuals signed an informed consent form.

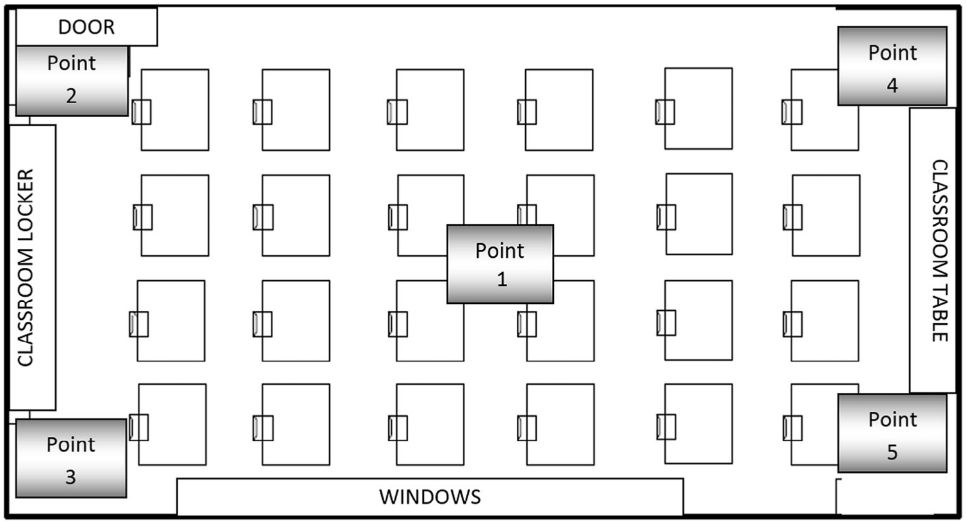

FIGURE 1. Background noise measurement points.

Cross-sectional data acquisition was obtained between May and June 2014 in a classroom at the Federal University of Minas Gerais.

The university room was chosen for the study environment with the background noise in the sound box. In this way, it is possible to control the environment and variables during measurement. This would not be possible in a public school, for example, where background noise is very variable. The background noise in the building where voice data were collected was low and did not interfere with the evaluation, which allowed simulation of the noise of a public school in the room used.

Twenty-seven women from 22 to 50 years old (mean = 29 years old) participated. Inclusion criteria were women between 20 and 50 without vocal complaints and with normal voices. Women were selected to best represent the demographics of teachers from public schools in Belo Horizonte, Brazil.[18] For voice quality analysis, auditory-perceptual analysis was completed by a speech-language pathologist to observe some evident vocal disorder, as well as a questionnaire regarding vocal symptoms: Voice Symptom Scale protocol validated in Brazilian Portuguese Voice Symptom Scale.[19]

Exclusion criteria were tobacco use, auditory, neurologic or respiratory complaints, pregnancy, premenstrual or menstrual period, incomplete dentition, and communication disorder observed during the speech-language pathology assessment.

The acoustics of the classroom were evaluated via observation of the characteristics of the room and measurement of the following acoustic parameters: background noise (L_{90}) and reverberation time (T_{30}).

L_{90} is a statistical measurement commonly employed to quantify background noise and involves calculation of the percentage of time in which a specific sound level was exceeded during the measurement interval. L_{90} is the sound level that was exceeded at 90% during the measurement time. Background noise (L_{90}) was measured during five 1-minute intervals of 1 second, in the frequency range of 63–8000 Hz. A sound pressure level (SPL) meter NTI-XL2 (NTI Audio AG, Principality of Liechtenstein) was used, which has a type I microphone (frequency range: 5 Hz–20 kHz, model M2230, omnidirectional free-field microphone; Phantom Power 48-V DC) and a capacity to measure in the frequency ranges of 63–8000 Hz. Measurements were performed according to the American National Standards Institute S12.60 (2010) norm (Figure 1).

Reverberation time (T_{30}) is a measure of the reverberation degree in a given space and is equal to the necessary time for a constant sound to decline by 60 dB after the sound source ceases (International Organization for Standardization [ISO] 3382-2, 2008). Reverberation time is expressed in seconds. According to American National Standards Institute S12.60-2010—Part 1, the maximum reverberation times allowed for 500, 1000, and 2000 Hz in learning spaces, unoccupied and furnished, are 0.6 second in a closed learning nucleus with a volume of <283 m^3 and 0.7 second with volumes of >283 and <566 m^3. For increased volumes, the norm does not alter reverberation time. Reverberation time was also evaluated using an SPL meter, NTI-XL2. All the procedures were performed according to the ISO 3382-2 (2008) norm, which defines the forms of measurement of the reverberation time.

The classroom where the recordings were made was a brick room, without acoustic treatment and a background noise of 43.92 dB (A), taken by the average value of five points of measurement in the room with furnishes such as chairs, computers, and one table. Reverberation time was 1.97 seconds as measured by the average value across 500, 1000, and 2000 Hz. The aforementioned values were similar to those found in classrooms in other county schools.[20] These data reinforce that the chosen classroom is representative of the classrooms of public schools evaluated previously in this city.

Two distinctive acoustic conditions were created:

(a) **Condition 1** (without noise): without acoustic treatment and without noise reproduction (background noise = 43.92 dB)
(b) **Condition 2** (with noise): room without acoustic treatment but with noise reproduction. The noise employed in condition 2 was recorded in county schools (~76.0 dB in an occupied room) and reproduced during data collection using an amplifying speaker KLH Multimedia

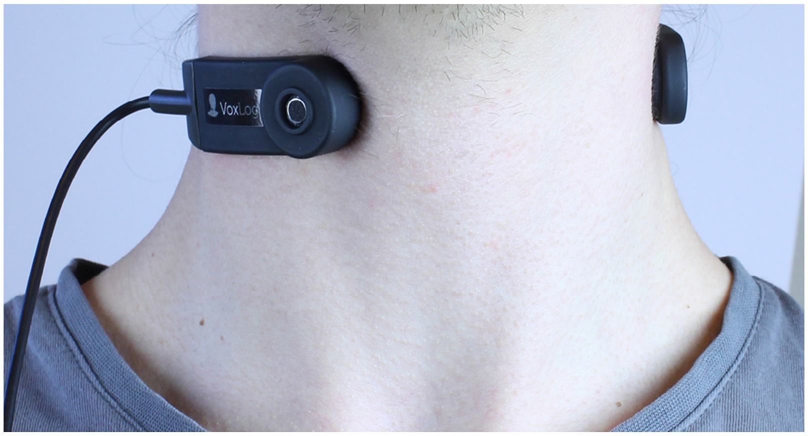

FIGURE 2. Placement of the VoxLog equipment electrodes. Source: http://www.biotechumea.se/sonvox-ab.

Systems C-521 (Cambridge, Massachusetts, EUA). The intensity of the noise was based on values previously measured in schools in Belo Horizonte, Brazil.[20] The sound speaker used was positioned 1.50 m from the participants, at the level of the head, right in front of them so that the sound could reach both ears equally.

Each participant was evaluated individually in the two aforementioned acoustic conditions. To obtain vocal dose, a vocal dosimeter (VoxLog, model 3.1; Sonvox) (Tvistevägen, Umeå, Sweden) was used, which was composed of a microphone, an accelerometer, and a portable unit that stores the vocal data. The accelerometer and the microphone were placed on the neck region close to the thyroid cartilage (Figure 2).

Data were stored in the portable unit of the vocal dosimeter and analyzed through the specific software of the VoxLog, composed of the following acoustic parameters of the voice:

(1) Fundamental frequency (F_0): the rate at which a waveform of voice is repeated per unit time and is measured in hertz.
(2) Vocal intensity: the amount of the energy of sound produced, which is related to the amplitude of the vocal fold and is measured in decibel SPL.
(3) Percentage of phonation: the relative time spent in phonation, compared with the elapsed time monitored, and is measured in percentage.[16]
(4) Cycle dose: the total quantity of complete oscillatory periods performed by the vocal folds in a set time,[14] that is, the number of vibration cycles of the vocal folds, in thousand units. The vocal dose was captured by the accelerometer of VoxLog. With this accelerometer, the vocal dose is calculated by the average of a simple threshold technique to distinguish vocalized and nonvocalized frameworks.[10] The cycle dose is calculated using the following equation.[17]

$$D_c = \frac{1}{1000}\int_0^{t_m} k_v F_0 dt \ cycles,$$

in which k_v is 1 for the presence of voice and 0 for the absence of voice, and F_0 is the fundamental frequency in hertz. As the number of cycles is quite high, this parameter is adapted to measure the dose in units of a thousand cycles.

The subjects were asked to read continuous text for 10 minutes. Two 10-minute readings were performed, one in each acoustic condition for a total of 20 minutes of recording. A rest interval of 15 minutes was provided between readings. It was considered that a sample of 10 minutes would be sufficient to evaluate the vocal parameters and to compare the vocal emission in the two evaluation situations.

The acoustic condition for each subject was randomly selected. An investigator was seated at the back of the room and the subjects were instructed to read at the vocal intensity deemed necessary to be heard at the back of the room (Figure 3).

The subjects were instructed to avoid abusive vocal behavior such as shouting, clearing their throat, or speaking in a strong intensity the day before data collection. The subjects were also advised to avoid caffeine, alcohol, and aspirin for 2 days before experimentation.

All statistical analyses were performed using *SPSS* software (v16.0) (SPSS Inc., Chicago USA). Analysis of central and dispersion tendencies was performed. To compare vocal parameters in both conditions, Student t tests were performed for the variables with normal distribution. The Wilcoxon test was employed for the variables with nonparametric distribution (fundamental frequency and vocal intensity). The level of significance considered was 5% ($P < 0.05$).

RESULTS

Results obtained from the analysis of the acoustic parameters in the different conditions are presented in Table 1.

F_0, vocal intensity, percentage of phonation, and cycle dose significantly increased with the addition of noise in the test environment simulating a noisier classroom as frequently found in county schools of Belo Horizonte, Brazil.

Figure 4 contains four box plots with the distributions of F_0, vocal intensity, percentage of phonation, and cycle dose.

The median values of F_0 were 234 Hz without noise and 279 Hz with noise. The box heights were 45.1 without noise and 52.4 with noise. The whiskers ranged from 201 to 357 without

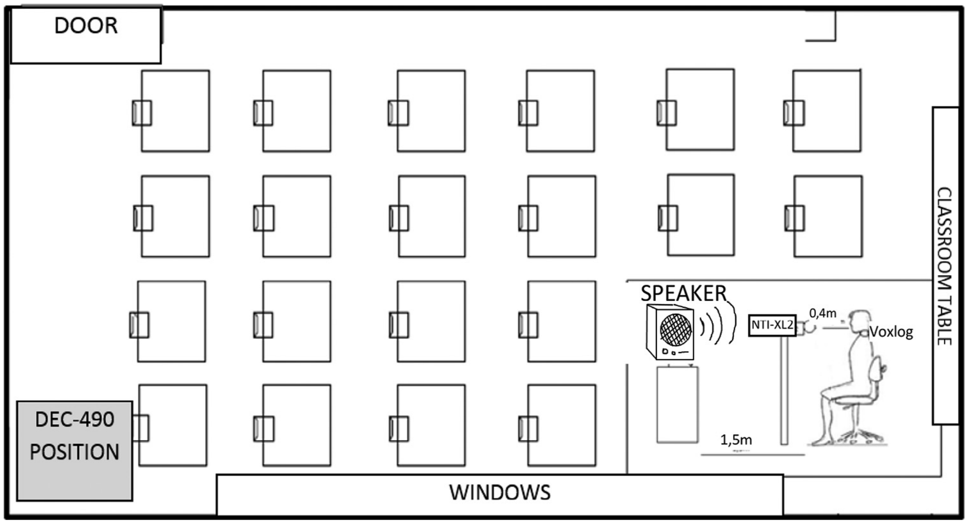

FIGURE 3. Position of the equipment and participants during voice evaluation.

noise and from 227 to 357 with noise. There were no outliers in this distribution.

The median values of vocal intensity were 80.6-dB SPL without noise and 87.5-dB SPL with noise. The box heights were 7.2 without noise and 3.93 with noise. The whiskers varied from 73.8 to 88.4 without noise and from 80.8 to 93.6 with noise. There was no outlier in this distribution.

The median values of the percentage of phonation were 53.2 without noise and 61.1 with noise. The box heights were 17.7 without noise and 10.0 with noise. The whiskers ranged from 26.6 to 64.1 without noise and from 56.1 to 73.3 with noise. The outliers of the percentage of phonation without noise were 15.7 and 16.3. The outliers of the percentage of phonation with noise were 14.4, 32.0, and 73.3.

The median values of the cycle dose were 76.6 vibration cycles without noise and 97.4 vibration cycles with noise. The box heights were 31.1 without noise and 22.2 with noise. The whiskers ranged from 24.8 to 107.7 without noise and from 69.0 to 136.1 with noise. The outliers of the cycle dose without noise were 0.4 and 9.45 vibration cycles. The outliers of the cycle dose with noise were 10.3, 24.2, 32.1, and 45.9 vibration cycles.

DISCUSSION

Voice production in women was analyzed in the current study to evaluate how noise in the environment influenced vocal dose and other acoustic parameters. Female participants were selected because the literature highlights that women have a higher predisposition for voice disorders,[21] and the vast majority of teachers are female.[22]

An observation should be made regarding the voice assessment for the selection of study participants. The women were evaluated through auditory-perceptual evaluation and were not subjected to endoscopic examination. However, the main objective of the study was to evaluate voices of women in the presence and the absence of noise. For this reason, such a detailed assessment of vocal disorders was not performed.

Voice use in very noisy environments can be associated with negative consequences for vocal health. With increased noise, increased intensity is required, as well as repetition of spoken content. For that reason, teachers tend to have higher vocal effort when teaching in noisy environments.[23] Prolonged use of the voice in noisy environments can contribute to the overload of the system

TABLE 1.
Description of the Acoustic Parameters of the Voice in the Two Acoustic Situations Evaluated From 27 Women Without Vocal Complaints

	Condition 1 (Without Noise)				Condition 2 (With Noise)				
Parameters	Average	Standard Deviation	Minimum Value	Maximum Value	Average	Standard Deviation	Minimum Value	Maximum Value	*P* Value
Fundamental frequency (Hz)	244.46	±28.54	201.69	322.88	274.31	±31.97	227.05	357.39	<0.001
Vocal intensity (dB SPL)	80.61	±3.80	73.88	88.44	87.07	±3.21	80.82	93.64	<0.001
Percentage of phonation (%)	50.66	±13.09	15.70	64.10	58.67	±11.47	14.40	73.30	<0.001
Cycle dose (number of vibration cycles)	74.13	±20.39	21.60	107.72	97.32	±22.18	24.25	136.17	<0.001

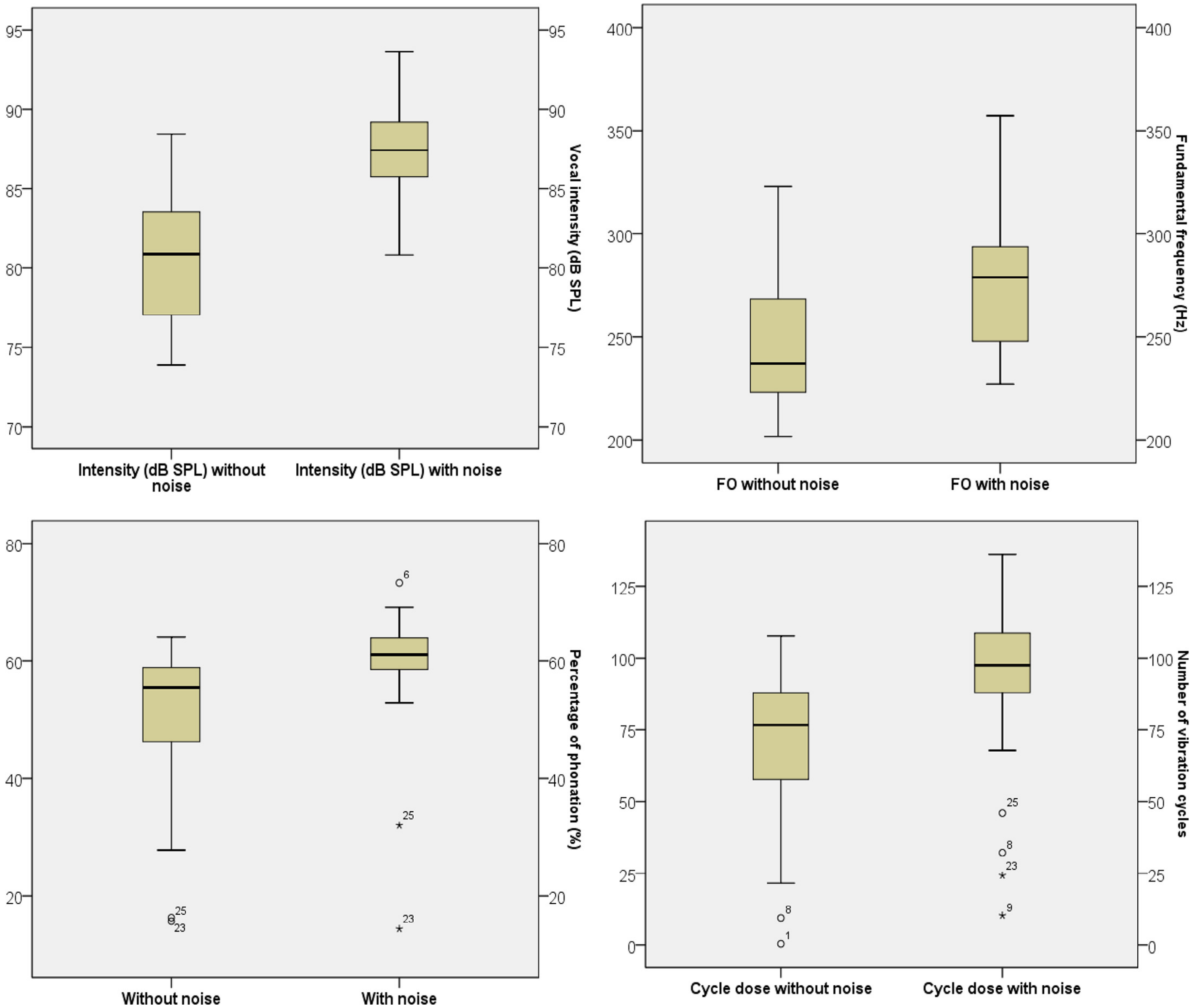

FIGURE 4. Graphic representation of the variables intensity level, fundamental frequency (F_0), percentage of phonation, and cycle dose according to the presence or the absence of noise. SPL, sound pressure level.

responsible for vocal production and also the onset of vocal symptoms.[23]

The results of the current study confirmed elevated F_0 in the presence of noise. A laboratory study that analyzed voice production in environmental noise showed that, to be heard in noise as is common with teachers, increased F_0 was common. These data suggest that higher F_0 in professional environments are likely due to high background noise in schools.[24] Such data concur with the results from the current study, which also found increased F_0 in a noisy environment.

Increase intensity was also observed in noise. A positive correlation has been reported between F_0 and intensity[25]; increased intensity is associated with increased F_0 likely related to increased tension of the vocal folds and increased subglottic pressure.[25] It is reasonable to hypothesize, therefore, that elevated F_0 could be the result of increased intensity. The higher the intensity, the higher the subglottic pressure and the higher the fundamental frequency generating higher impact stresses on the vocal fold tissue.[26] In general, most teachers tend to maintain a vocal intensity around 10–15 dB above environment noise, which is above the vocal intensity of daily conversation.[27] With increased background noise, vocal intensity increases. If this demand becomes continuous, it could tax the structures responsible for phonation and could eventually be associated with lesions of the vocal folds and altered quality of voice.[28]

Recent data suggest that the use of a voice amplifier may provide some degree of enhanced vocal health for teachers as it favors decreased intensity with reduced effort while teaching.[29]

The results of the current study suggest that increased noise in the environment contributed to increased percentage of phonation and cycle dose. Such findings confirm the results found in a recent study that compared vocal loads of kindergarten and elementary school teachers and associated increased vocal dose with the presence of environmental noise.[15] It is possible to suppose, therefore, that increased environment noise may overload the phonatory system as it elevates the duration of voice use with increased impact stress. Increased vocal dose caused by a background noise in the classroom may be a risk factor for the vocal health of the teachers.[30]

Researchers from many different countries have noticed the high prevalence of voice disorders in teachers in comparison with the general population. In Brazil, the prevalence rate of dysphonia in teachers is 11.6%.[31]

Although the risks of noise on the vocal health of professionals are known, no regulations currently exist to prevent these issues.[16] Suitable ergonomic conditions related to classroom noise are critical factors in the maintenance of vocal health.

To develop appropriate occupational health regulations for professions with high vocal demands, it is necessary to demonstrate, through future research, patterns of the development of voice disorders as a function of voice use in the workplace.[17] Further investigation regarding vocal dose are necessary to determine, for instance, unhealthy vocal doses[16] and the connection between these measurements and the occupational environment to ultimately maintain optimal health in teachers.

CONCLUSION

A positive relation between vocal parameters and the presence of excessive noise in the environment was observed. With increased noise, increased vocal intensity, fundamental frequency, percentage of phonation, and cycle dose of the voice were observed.

During the course of the study, the noise present in the school environment bothers teachers and students and can interfere with learning and teachers' performance and the progress of activities.

The speech therapist inserted in the school environment should act as a health promoter, collaborating to propagate and raise awareness about self-care measures, aiming at reducing the impact of noise in the teaching learning process, as well as in the general health of teachers and students.

Only through the joint actions of a speech therapist and education and engineering professionals will it be possible to improve working conditions for teachers and to provide adequate learning environments.

It is hoped that the present study may contribute to the research in this area and encourage more and more researchers to dedicate themselves to this subject so needy in advanced research to base the necessary practical actions.

REFERENCES

1. World Health Organization—WHO. Guidelines for community noise. London, 1999.
2. Dreossi RCF, Momensohn-Santos TM. Noise and its interference over students in a classroom environment: literature review. *Pró-Fono*. 2005;17:251–258.
3. Klatte M, Lachmann T, Meis M. Effects of noise and reverberation on speech perception and listening comprehension of children and adults in a classroom-like setting. *Noise Health*. 2010;12:270–282.
4. Servilha EAM, Delatti MA. College students' perception of classroom noise and its consequences on learning quality. *ACR*. 2014;19:138–144.
5. Gonçalves VSB, Silva LB, Coutinho AS. Noise compromising the speech intelligibility for teachers. *Produção*. 2009;19:466–476.
6. Dreossi RCF, Momensohn-Santos TM. Noise and learning. *Rev Psicopedagogia*. 2004;21:38–47.
7. Mendes ALF, Lucena BTL, Araújo AMGD, et al. Teacher's voice: vocal tract discomfort symptoms, vocal intensity and noise in the classroom. *Codas*. 2016;28:168–175.
8. Zollinger SA, Brumm H. The Lombard effect. *Curr Biol*. 2011;21:pR614–R615.
9. Ribeiro MB, Gama ACC, Bassi IB, et al. Vocal, laryngeal and self-perception measurements of dysphonic teachers: analysis after voice therapy. *CEFAC*. 2013;15:616–641.
10. Carullo A, Vallan A, Astolfi A. Design issues for a portable vocal analyzer. *IEEE Transactions on Instrumentation and Measurement*. 2013;62:1084–1093.
11. Martins RH, Pereira ER, Hidalgo CB, et al. Voice disorders in teachers: a review. *J Voice*. 2014;6:716–724.
12. Nelson PB, Soli SD, Seltz A. Acoustical barriers to learning. A Publication of the Technical Committee on Speech Communication of the Acoustical Society of America, 2002.
13. Svec JG, Popolo PS, Titze IR. Measurement of vocal doses in speech: experimental procedure and signal processing. *Logoped Phoniatr Vocol*. 2003;28:181–192.
14. Titze IR, Svec JG, Popolo PS. Vocal dose measures: quantifying accumulated vibration exposure in vocal fold tissues. *J Speech Lang Hear Res*. 2003;46:919–932.
15. Remacle A, Morsomme D, Finck C. Comparison of vocal loading parameters in kindergarten and elementary school teachers. *J Speech Lang Hear Res*. 2014;57:406–415.
16. Gaskill CS, O'Brien SG, Tinter SR. The effect of voice amplification on occupational vocal dose in elementary school teachers. *J Voice*. 2012;26:666e19–666e27.
17. Rantala L, Vilkman E, Bloigu R. Voice changes during work: subjective complaints and objective measurements for female primary and secondary schoolteachers. *J Voice*. 2002;16:344–355.
18. Medeiros AM, Barreto SM, Assunção AA. Voice disorders (dysphonia) in public school female teachers working in Belo Horizonte: prevalence and associated factors. *J Voice*. 2008;22:676–687.
19. Moreti F, Zambon F, Oliveira G, et al. Cross-cultural adaptation, validation, and cutoff values of the Brazilian version of the Voice Symptom Scale—VoiSS. *J Voice*. 2014;28:458–468.
20. Rabelo ATV, Santos JN, Oliveira RC, et al. Effect of classroom acoustics on the speech intelligibility of students. *Codas*. 2014;26:360–366.
21. Hunter EJ, Titze IR. Variations in intensity, fundamental frequency, and voicing for teachers in occupational versus non-occupational settings. *J Speech Lang Hear Res*. 2010;53:862–875.
22. Marçal CCB, Peres MA. Alteração vocal auto-referida em professores: prevalência e fatores associados. *Rev Saúde Públ*. 2011;45:503–511.
23. Cutiva LC, Burdorf A. Effects of noise and acoustics in schools on vocal health in teachers. *Noise Health*. 2015;17:17–22.
24. Sodersten M, Ternstrom S, Bohman M. Loud speech in realistic environmental noise: phonetogram data, perceptual voice quality, subjective ratings, and gender differences in healthy speakers. *J Voice*. 2005;19:29–46.
25. Behlau M. *O Livro do Especialista*, Vol. I. Rio de Janeiro: Revinter; 2004.
26. Titze IR. Mechanical stress in phonation. *J Voice*. 1994;8:99–105.
27. Bovo R, Trevisi P, Emanuelli E, et al. Voice amplification for primary school teachers with voice disorders: a randomized clinical trial. *Int J Occup Med Environ Health*. 2013;26:363–372.
28. Guidini RF, Bertoncello F, Zanchetta S, et al. Correlations between classroom environmental noise and teachers' voice. *Rev Soc Bras Fonoaudiol*. 2012;17:398–404.
29. Simões-Zenari M, Bitar ML, Nemr NK. The effect of noise on the voice of preschool institution educators. *Rev Saúde Públ*. 2012;46:657–664.
30. Vilkman E. Occupational risk factors and voice disorders. *Logop Phoniatr Vocol*. 1996;21:137–141.
31. Behlau M, Zambon F, Guerrieri AC, et al. Epidemiology of voice disorders in teachers and nonteachers in Brazil: prevalence and adverse effects. *J Voice*. 2012;26:665, e9-665.