Objective Voice Parameters in Colombian School Workers with Healthy Voices

Parámetros objetivos de la voz de trabajadores escolares colombianos con voces saludables

Parâmetros de voz objetivas de funcionários da escola colombianos com vozes saudáveis

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Abstract

Objectives: To characterize the objective voice parameters among school workers, and to identify associated factors of three objective voice parameters, namely fundamental frequency, sound pressure level and maximum phonation time. *Materials and methods*: We conducted a cross-sectional study among 116 Colombian teachers and 20 Colombian non-teachers. After signing the informed consent form, participants filled out a questionnaire. Then, a voice sample was recorded and evaluated perceptually by a speech therapist and by objective voice analysis with PRAAT software. Short-term environmental measurements of sound level, temperature, humidity, and reverberation time were conducted during visits at the workplaces, such as classrooms and offices. Linear regression analysis was used to determine associations between individual and work-related factors and objective voice parameters. *Results*: Compared with men, women had higher fundamental frequency (201 Hz for teachers and 209 for non-teachers vs. 120 Hz for teachers and 127 for non-teachers) and sound pressure level (82 dB vs. 80 dB), and shorter maximum phonation time (around 14 seconds vs. around 16 seconds). Female teachers younger than 50 years of age evidenced a significant tendency to speak with lower fundamental frequency and shorter MPT compared with female teachers older than 50 years of age. Female teachers had significantly higher fundamental frequency (66 Hz), higher sound pressure level (2 dB) and short phonation time (2 seconds) than male teachers. *Conclusion*: Female teachers younger than 50 years of age had significantly lower F0 and shorter MPT compared with those older than 50

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years of age. The multivariate analysis showed that gender was a much more important determinant of variations in F0, SPL and MPT than age and teaching occupation. Objectively measured temperature also contributed to the changes on SPL among school workers.

Keywords: Voice complaints, Objective voice analysis.

Resumen

Objetivos: Caracterizar los parámetros objetivos de la voz en trabajadores escolares e identificar los factores asociados de tres parámetros objetivos de la voz (frecuencia fundamental, presión sonora y tiempo máximo de fonación). *Materiales y métodos*: Estudio transversal en el que participaron 116 profesores y 20 no profesores colombianos. Después de firmar el consentimiento informado, los participantes diligenciaron un cuestionario. Posteriormente, grabaron una muestra de voz, la cual fue analizada, perceptualmente, por una fonoaudióloga y, objetivamente, con el software PRAAT. Se realizaron mediciones ambientales de niveles de ruido, temperatura, humedad y tiempos de reverberación durante las visitas a los lugares de trabajo, tales como salones y oficinas. Análisis de los factores individuales y ocupacionales asociados con los parámetros de la voz fueron realizados por medio de regresiones lineales. *Resultados*: Comparadas con sus pares masculinos, las trabajadoras escolares registraron frecuencia fundamental más aguda (201 Hz para las profesoras y 209 para las no-profesoras frente a 120 Hz para los profesores y 127 para los no-profesores) e intensidad más alta (82 dB frente 80 dB), y tiempo máximo de fonación más corto (14 segundos aproximadamente frente a 16 segundos aproximadamente). Las profesoras menores de 50 años evidenciaron una tendencia significativa a producir una frecuencia fundamental más baja y un TMF más corto, comparadas con las profesoras mayores de 50 años. Las profesoras registraron frecuencia fundamental significativamente más alta (66 Hz), intensidad más alta (2 dB) y tiempo máximo de fonación más corto (2 segundos) comparadas con los profesores. *Conclusión*: Las profesoras menores de 50 años registraron frecuencia fundamental más baja y TMF más corto compradas con las profesoras mayores de 50 años. El análisis multivariado mostró que género fue una variable mucho más importante para determinar la variación en F0, SPL y TMF que edad u ocupación. La temperatura dentro de los lugares de trabajo (medida objetivamente) también contribuye a los cambios en intensidad de la voz entre los trabajadores escolares.

Palabras clave: Quejas vocales, análisis objetivo de la voz.

Resumo

Objetivos: Caracterizar os parâmetros objetivos da voz em trabalhadores escolares, e identificar os fatores associados de três parâmetros objetivos da voz (frequência fundamental, pressão sonora e tempo máximo de fonação). *Métodos*: Estudo transversal no que participaram 116 professores e 20 professores não colombianos. Depois de assinar o consentimento informado, os participantes preencheram um questionário. Posteriormente, gravaram uma amostra de voz, a qual foi analisada perceptualmente por uma fonoaudióloga; e objetivamente utilizando o software PRAAT. Realizaram-se medições ambientais de níveis de barulho, temperatura, humidade e tempos de reverberação durante as visitas aos lugares de trabalho, tais como salas e escritórios. Análise dos fatores individuais e ocupacionais, associados com os parâmetros da voz, foi realizada através e

regressões lineares. *Resultados*: comparadas com os seus pares masculinos, as trabalhadoras escolares registraram frequência fundamental mais aguda (201 Hz para as professoras e 209 para as não-professoras vs. 120 Hz para os professores e 127 para os não-professores) e intensidade maior (82 dB vs. 80 dB), e tempo máximo de fonação menor (14 segundos aproximadamente). As professoras menores de 50 anos evidenciaram uma tendência significativa a produzir uma frequência fundamental mais baixa e um MF mais curto comparadas com as professoras maiores de 50 anos. As professoras registraram frequência fundamental significativamente maior (66Hz), intensidade maior (2 dB) e tempo máximo de fonação mais curto (2 segundos) comparadas com os professores. *Conclusão*: as professoras menores de 50 anos registraram frequência fundamental mais baixa e TMF mais curto compradas com as professoras maiores de 50 anos. A análise multivariada mostrou que gênero foi uma variável muito mais importante para determinar a variação em F0, SPL e TMF que idade ou ocupação. A temperatura dentro dos lugares de trabalho (mesurada objetivamente) também contribui às mudanças em intensidade da voz entre os trabalhadores escolares.

Palavras-chave: Queixas vocais, análise objetiva da voz.

Introduction

The voice has become a primary tool of work in many occupations, such as secretaries, musicians and teachers (1). Previous studies have reported a higher occurrence of voice disorders among teachers compared with other professional voice users. However, estimates of the prevalence in teachers vary considerably, which can partly be explained by the use of different assessment methods of voice disorders (2).

A recent systematic review reported that studies on voice disorders among teachers have mainly relied on self-reports (2). Very few studies have included in their assessments perceptual analysis of voice or objective measurements of voice parameters (3-6).

Although objective assessment of voice is more expensive and time-demanding with high technical and personnel requirements compared with subjective assessment of voice, such as self-reports or perceptual analysis, it is recommended to complement self-reports with such measurements in order to describe comprehensively the voice functioning. Self-reports are influenced by internal standards, whereas objective voice parameters depend less on internal criteria, provide information that could be compared with "normalized reference values", and present guidance to determine the appropriate interventions to improve voice quality (7-8).

To our knowledge, there is a lack of studies on objective voice parameters among Colombian school workers (as professional voice users) with healthy voices; knowledge required to define "reference values" that allow identifying objectively the presence or absence of voice disorders among these professional voice users.

Furthermore, to the best of our knowledge, there is a dearth of studies on the association between objective voice parameters, such as fundamental frequency (F0), sound pressure levels (SPL), jitter, shimmer and maximum phonation time (MPT) with individual and work-related factors. This research is important for a better understanding of the contribution of these factors to diagnostic procedures.

Therefore, we conducted a cross-sectional study within 136 Colombian school workers in twelve public schools in Bogota. Our aims were to characterize the objective voice parameters among school workers (teachers and non-

teachers), and to identify the factors associated with the F0, SPL and the MPT.

Materials and Methods

This cross-sectional study is part of a larger research on voice disorders among primary and secondary public schools' teachers in Bogota, Colombia. Detailed information on the sampling process and the data collection procedures has been described in previous publications (9-11).

Design and Participants

Between February and November 2012, we conducted a longitudinal study among twelve public schools selected by convenience sampling by the Department of Education of Bogota. This study is focused on cross-sectional results on objective voice parameters among school workers with healthy voices assessed in February and March (at the beginning of the school year).

After approval of the Department of Education of Bogota and the school board of each school, the main researcher had meetings with the school workers to inform about the aims of the study and to invite them to be part of the study. A total of 682 school workers (teachers, secretaries, head teachers, librarians and coordinators) participated in this research, 136 of whom had self-reported healthy voice confirmed by perceptual assessment by a speech therapist, and who therefore made up the study population. The study protocol was approved by the Medical Ethics Committee of the Universidad del Rosario in Bogota, and complied with the ethical principles embodied in the Helsinki Declaration.

Data Collection Procedures

Questionnaire

For this study, we designed a questionnaire based on previous publications which consisted of 71 questions for teachers and 63 questions for non-teachers (12, 13). The questionnaire included questions on individual characteristics, voice functioning, lifestyle habits, work-related factors, and health conditions previously reported to be associated with the presence of voice complaints. More detailed information on the design and characteristics of the questionnaire has been described previously (9).

Objective Environmental Measurements

For objective measurements a total of 338 workplaces (classrooms, playgrounds, offices, and libraries) were visited. We measured sound level (SL), temperature, and humidity by means of the 4 in 1 digital multi-function Environment-Meter Mod WK040 during actual working activities . In addition, we measured reverberation time (RT) using the Room Acoustic Measurement System software into non-occupied workplaces during weekends or school rest periods. We also measured sound level (SL) outside school facilities to identify the highest noise level at a distance of two meters from walls (14). For further analysis, objective measures of environmental factors were dichotomized, whereby subjects under the 75th quartile were used as reference group. The objective environmental measurements are described in detail in a previous publication (10).

Voice Samples

Voice samples were recorded in a silent room of the school in order to avoid as much as possible background noise. We collected two voice samples: One reading sample and one vowel sample. Participants were instructed to produce both voice samples at a comfortable and conversational pitch, with loudness as naturally as possible, not in a singing voice. The samples were recorded using portable digital recorders

(SonyTM, OlympusTM and RCATM), which were placed at a short distance of 5-6 cm from their mouths. This short distance was used to minimize possible effects of room acoustics (15).

The first voice sample recorded was the reading sample used for perceptual assessment. The reading consists of a fragment of the text "El Caballero de la Armadura Oxidada"("The Knight in Rusty Armor", a standardized text in Spanish with 223 words) (16). The second voice sample was the sustained production of the vowel /i/, as long as possible, which was used for objective voice assessment.

Perceptual Assessment by Speech Therapist

In this study, the perceptual assessment of voice was performed by means of the GRBAS scale, proposed by the Japanese Society of Logopedics and Phoniatrics. This scale consists of five components (overall quality (G), roughness (R), breathiness (B), asthenia (A), and stress (S)) evaluated on a 4-point rating scale (0 for normal, 1 for slight dysphonia, 2 for moderate dysphonia, and 3 for severe dysphonia) (17). As in previous researches, a G score was used as a summary measure based on the other four components (18). The overall quality (G score) was expressed by the highest score on any of the four specific components. All perceptual analyses were performed by the main researcher, a speech therapist with ample experience in perceptual voice assessment. For the perceptual assessment, the main researcher was blinded for the information from the questionnaire concerning self-reported voice symptoms.

Definition of Healthy Voices

In this study, we used two measures to identify those school workers with healthy voices. Firstly, the dichotomous question "Have you noticed voice symptoms in the past month?" was used to define the presence or absence of self-reported voice symptoms (12, 13). Secondly, the GRBAS scale was used to perform the perceptual assessment of voice. Those school workers who reported no voice symptoms and who were perceptually classified as without voice disorders were defined as "school workers with healthy voices".

Objective Voice Analysis

For this study, the objective assessment of voice consisted of the analysis of fundamental frequency in Hz (F0), sound pressure level in dB (SPL), pitch perturbation in percentage (Jitter), amplitude perturbation in dB (Shimmer), and maximum phonation time in seconds (MPT). A 1-second segment from the midpoint of the vowel produced by each participant was subjected to objective analysis of voice. For pitch analysis, the default range used was 50-300Hz for male voice samples and 50-500Hz for female voice samples. Default settings were used for all other objective parameters. All objective analyses were performed by means of the software PRAAT (19). For further analysis, we calculated means and standard errors (SE).

Statistical Analysis

Epi-info 3.5.3. (CDC/2011) software was used for data entry, and SPSS 20 software was used for statistical analysis. Since for some independent variables a few missing values occurred, multiple imputation was performed. The statistical analysis was conducted on the study population with complete information on all variables. Descriptive statistics were used for characteristics of the study population and for objective voice parameters. Since hormonal changes that affect the voice of both men and women start around the age of 50, in further analysis the variable age was dichotomized using a cut-off value of 50 years of age (20). We calculated

means and standard errors (SE) for objective voice parameters stratified by gender and age. We used linear regression to investigate associations between the fundamental frequency, sound pressure level and maximum phonation time with socio-demographic characteristics, work-related factors, and health-related conditions. For the independent variables, those with a p-value lower than 0.20 in the univariate analysis were included in the multivariate analyses in order to avoid residual confounding, and were only retained if the p-value reached the conventional level of significance of 0.05 (21). The magnitude of the associations was expressed by the regression coefficient beta (β), and the standard error (SE).

Results

Participant Characteristics

As presented in Table 1, compared with non-teachers, teachers with healthy voices were younger and more often women. Around 60 % of teachers reported high noise levels in the workplace, whereas 45 % of non-teachers reported this condition.

Table 1. Characteristics of 136 school workers of 12 public schools in Bogota, Colombia with perceptually identified healthy voices

	Teachers (n=116)		Non-teachers (n=20)	
Variable	N	%	N	%
Socio-demographics				
< 50 years of age	85	73	7	35
Female	65	56	7	35
Health-related conditions				
Respiratory diseases	26	22	6	30
Gastrointestinal diseases	41	35	9	45
Hearing impairment	24	21	3	15
Self-reported work-related factors				
High noise levels in workplace	72	62	9	45
Poor acoustics in workplace	54	47	9	45
Dry air in workplace	52	45	8	40
Large temperature variations in workplace	56	48	9	45
Objectively measured work-related factors				
High noise levels outside school (dB(A))	13	11	3	15
High background noise in workplace (dB(A))	24	21	0	0
Large reverberation time in workplace (seconds)	36	31	5	25
High humidity in workplace (RH)	21	18	6	30
High temperature in workplace (°C)	40	34	5	25

Objective Voice Parameters among School Workers

Table 2 shows the results of the objective voice parameters stratified by teaching occupation and gender. Compared with men, women had statistically significant higher fundamental frequencies. Although women showed higher SPL and shorter MPT, these differences were not statistically significant.

Table 3 shows the descriptive analysis stratified by teaching occupation and age. Compared with school workers older than 50 years of age, those younger than 50 years of age showed higher F0 and SPL and shorter MPT. Nevertheless, these differences were not statistically significant.

Figure 1 shows the analysis of fundamental frequency, stratified by teaching occupation, gender and age. Some variation was observed for age and gender. Male teachers and non-teachers younger than 50 years of age showed a tendency to speak with higher fundamental frequency, but the difference was not statistically significant. As shown in figure 2 to figure 4, no significant differences were found in spl, jitter or shimmer in the analysis stratified by teaching occupation, gender and age. Figure 5 shows that younger female teachers had significantly shorter mpt compared with female teachers older than 50 years of age.

Table 2. Voice acoustic parameters stratified by gender among 116 teachers and 20 non-teachers in twelve public schools in Bogota, Colombia

	Teachers (n=116)				Non-teachers (n=20)			
	Female (n=65)		Male (n=51)		Female (n=7)		Male (n=13)	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Fundamental frequency (Hz)*	200.6	8,4	120.3	4,4	209.4	15,2	127.0	9,6
Sound pressure level (dB)	82,3	0,5	80,2	1,1	82,2	1,5	79,9	1,5
Jitter (%)	1,0	0,2	0,6	0,1	0,5	0,3	0,5	0,1
Shimmer (dB)	0,7	0,1	0,6	0,1	0,6	0,1	0,5	0,1
Maximum phonation time (sec.)	14,7	0,7	16,4	0,8	12,9	2,5	17,3	1,7

* t- test, p<0,05

SE= Standard error of the mean

Table 3. Voice acoustic parameters stratified by age among 116 teachers and 20 non-teachers in 12 public schools in Bogota, Colombia

	Teachers (n=116)				Non-teachers (n=20)			
	< 50 years of age (n=85)		≥ 50 years of age (n=31)		< 50 years of age (n=7)		≥ 50 years of age (n=13)	
Variable	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Fundamental Frequency (Hz)	169.8	6,4	153.1	15,8	164.2	26,2	150.6	14,4
Sound pressure level (dB)	81,6	0,6	80,8	1,2	81,7	1,7	80,2	1,5
Jitter (%)	0,8	0,2	1,0	0,3	0,6	0,3	0,5	0,1
Shimmer (dB)	0,6	0,1	0,7	0,1	0,4	0,1	0,6	0,1
Maximum phonation time (sec.)	14,8	0,6	17,1	1,0	13,8	2,9	16,8	1,6

SE= Standard error of the mean

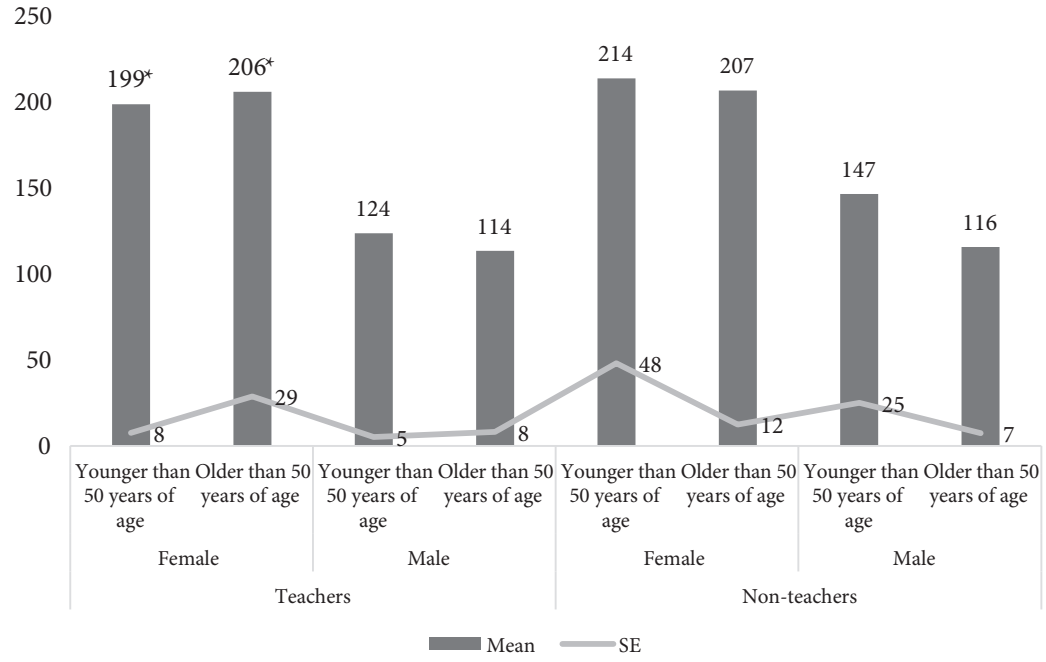

Figure 1. Fundamental frequency stratified by teaching occupation, gender and age among 116 teachers and 20 non-teachers in twelve public schools in Bogota, Colombia

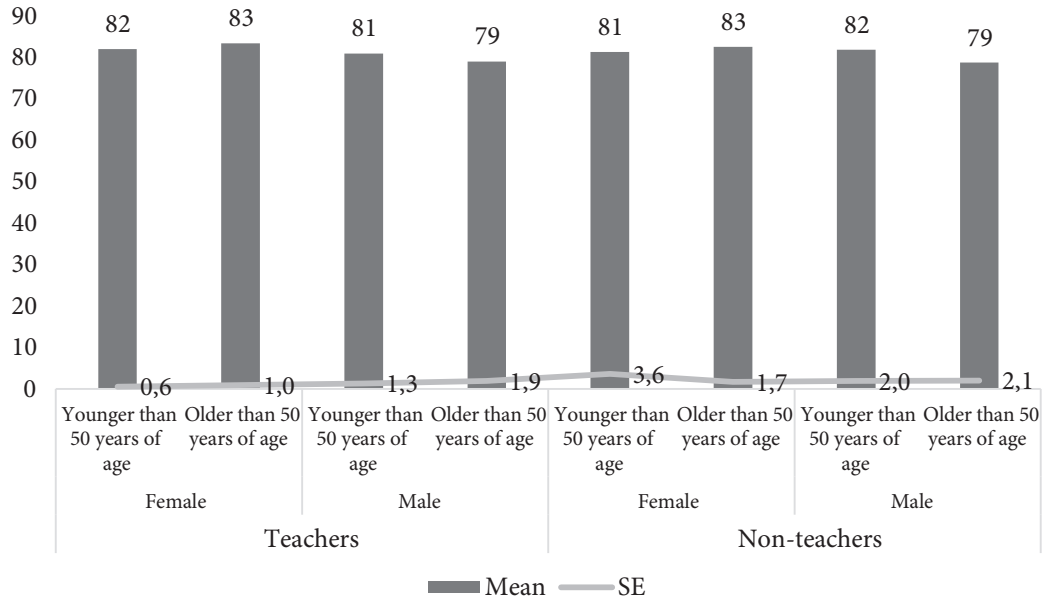

Figure 2. Sound pressure level stratified by teaching occupation, gender and age among 116 teachers and 20 non-teachers in twelve public schools in Bogota, Colombia

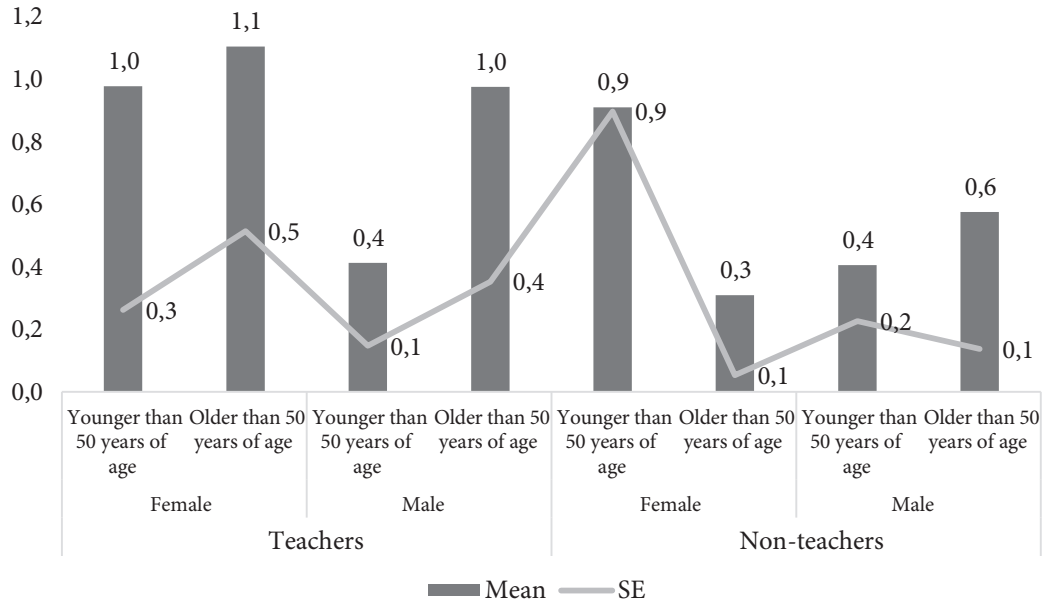

Figure 3. Jitter stratified by teaching occupation, gender and age among 116 teachers and 20 non-teachers in twelve public schools in Bogota, Colombia

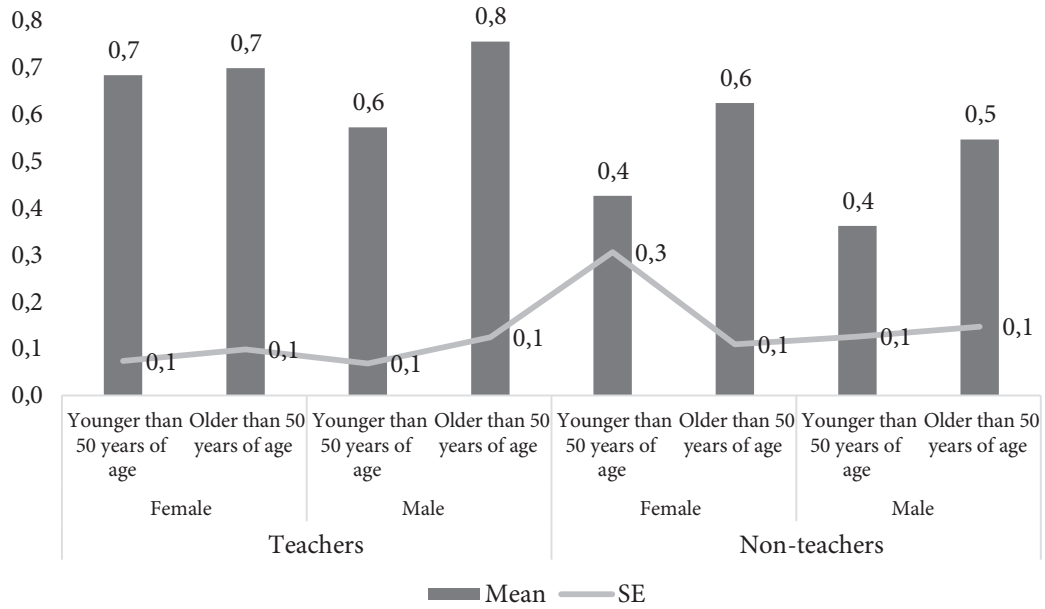

Figure 4. Shimmer stratified by teaching occupation, gender and age among 116 teachers and 20 non-teachers in twelve public schools in Bogota, Colombia

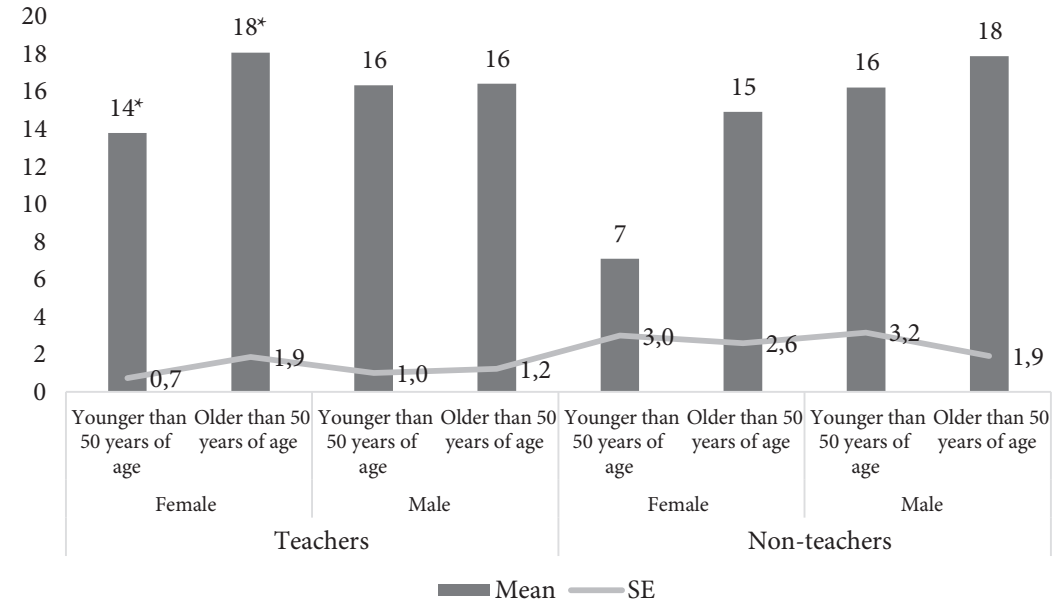

Figure 5. maximum phonation time stratified by teaching occupation, gender and age among 116 teachers and 20 non-teachers in twelve public schools in Bogota, Colombia

Factors Associated with Objective Voice Characteristics in School Workers

Table 4 shows those factors that were found to be associated with F0, SPL and MPT in multivariate linear regression analyses. The multivariate analysis shows that gender was an important determinant, with significantly higher F0 (66 Hz) and SPL (2 dB) and significantly shorter MPT (2 seconds) for female school workers. Gender was much more important than age and teaching occupation, since age and teaching-related differences became non-significant after adjustment for gender.

Table 4. Multivariate associations between fundamental frequency, sound pressure levels and maximum phonation time with socio-demographic characteristics, health-related conditions and work-related factors of 136 school workers without voice complaints in twelve public schools in Bogota, Colombia

	Fundamental frequency		Sound Pressure levels		Maximum phonation time	
Variable	Beta	SE	Beta	SE	Beta	SE
Socio-demographics						
Female gender	65,8*	7,6	1,8*	0,9	-2,3*	0,8
< 50 years of age	-9,5	7,4	-1,1	1,1	1,4	1,0
Teaching occupation	-1,5	9,7				
Health-related conditions						

	Fundamental frequency		Sound Pressure levels		Maximum phonation time	
Respiratory diseases						
Gastrointestinal diseases	9,1	8,4	1,0	0,9		
Hearing impairment	-12,3	10,9	-2,0	1,3		
Self-reported work-related factors						
High noise in workplace	5,5	7,6	1,2	0,9		
Poor acoustics in workplace						
Dry air in workplace						
Large changes in temperature in workplace	6,6	7,1				
Objectively measured work-related factors						
High noise outside school (dB(A))			1,4	1,3		
High background noise in workplace (dB(A))					1,1	1,1
Large reverberation time in workplace (sec)	-15,4	9,3				
High humidity in workplace (RH)					1,6	1,1
High temperature in workplace (°C)			-3,7*	1,0	-0,5	0,9

* $p<0.05$

Discussion

In this study, we investigated the objective voice parameters among school workers (teachers and non-teachers). In addition, we evaluated the associations between the F0, spl and the mpt with socio-demographic characteristics, health-related conditions and work-related factors. Our findings showed that the female gender is associated with higher F0, SPL and shorter MPT among school workers with healthy voices.

Since no previous studies have reported "reference values" of objective voice parameters among Colombian teachers or non-teachers, it is not possible to compare our results with Colombian standards. In this study, we found mean values of fundamental frequency of around 200 Hz and SPL of around 82 dB for female teachers. These findings are in line with the results of Laukkanen et al (2008), who found among Finnish female teachers average values for F0 of 195 Hz – 202 Hz, and for SPL of 83 dB – 84 dB (5). Among non-teachers, the mean value of F0 of around 209 Hz is in line with the results of Finger et al (2009), who reported a mean value of 226 Hz for vowel /i/ among Brazilian females (8).

We found that school workers younger than 50 years of age had a higher F0 compared with those older than 50 years. This finding is in agreement with previous studies that reported lower pitch in female voices and male voices with aging. Nevertheless, this difference was not statistically significant (20, 22). The multivariate analysis showed that gender was much more important than age. The observation that female teachers younger than 50 years of age had a lower F0 may be partly explained by the clinical point of view that physiological changes in ligaments, cartilages and the vocal folds due to aging as well as hormonal changes will decrease the vibration rate of the vocal folds, and consequently the pitch of the voice (23). Future research is needed to study the connection of aging with the changes of acoustic voice parameters among different occupations.

In this study, we found that Colombian female teachers can sustain a vowel sound with a relatively comfortable pitch and loudness around 15 seconds, and male school workers during around 17 seconds. This finding is in discordance with the results of one Spanish study that reported that Spanish women sustain a vowel sound during 21 seconds in average, and Spanish men during 26 seconds (24). These differences between Spanish and Colombian population may be partly attributed to differences in voice use, as well as individual factors. To the best of our knowledge, comparable information on MPT from school workers in other countries is not available in the scientific literature and, therefore, it cannot be established whether local and cultural factors have influenced our findings on this objective parameter of voice. In addition, our results suggest that female teachers younger than 50 years of age can sustain a vowel sound with a relatively comfortable pitch and loudness for shorter time compared with those older than 50 years of age. However, the multivariate analysis showed that gender was a much more important associated factor than age.

We would like to highlight our findings on the associated factors of the objective voice parameters. To the best of our knowledge, there is a lack of studies assessing the influence of individual and work-related factors on objective voice parameters, such as F0, SPL and MPT, among school workers; therefore, it is not possible to compare our results with previous studies. The results of this study suggest that, after adjustments for those variables significantly associated in the univariate analysis, gender is an underlying cause of part of the variations of F0, SPL and MPT. The modest difference in F0 between male and female is in line with previous studies, and may be partly explained by the length in the vocal folds, which is longer in men (225, 26).

The univariate analysis showed that two objectively measured physical condition (noise levels outside school and high temperature in workplace), and one self-reported work-related factor (noise) were associated with sound pressure level of voice among Colombian school workers. However, in the multivariate analysis only objectively measured temperature remained associated with SPL of voice. It seems that school workers working in workplaces with a temperature higher than 23°C use their voices around 4dB lower compared with those who work in workplaces with temperatures below 23°C. The relation between environmental temperature and voice use intensity is still unclear. Nevertheless, previous studies on the influence of temperature in voice production have highlighted the association between temperature, and muscle function and laryngeal viscosity (27, 28). Since regulation of vocal intensity is partly controlled by the tension of the vocal folds, it seems likely that a higher temperature reduces muscle tension of vocal folds and, thereby, increases the airflow during phonation and therefore the vocal intensity. Future studies are required to explore this relationship in more detail.

A major limitation of this study was the cross-sectional study design, which does not allow insight into the causality of the reported associations: we have no information on the relationship over time between the factors identified as being associated and the changes in the objective voice parameters. A second limitation is related to missing data, since around 9 % of participants did not record a voice sample. However, some authors suggest that statistical analysis with less than 10 % of missing data is not likely to be biased (21). A third limitation is that the perceptual assessment was performed

by a single listener, which may have reduced the reliability of ratings.

In conclusion, this study among school workers with healthy voices presented indications that female teachers younger than 50 years of age had significantly lower F0 and shorter MPT compared with those older than 50 years of age. The multivariate analysis showed that gender was a much more important determinant of variations in F0, SPL and MPT than age. Objectively measured temperature also contributed to the changes on SPL among school workers.

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