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# CLASSROOM ACOUSTICS AND RECOVERY OF VOICE COMPLAINTS AMONG TEACHERS

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**Abstract**
Objective: To assess the association between classroom acoustics and recovery of voice complaints. Methods: A longitudinal study was conducted with an eleven-month follow-up among 449 teachers. Results: Teachers who reported poor acoustic conditions in the classrooms were less likely to recover from voice complaints (OR=0.52). Conclusion: This longitudinal study indicates that self-perceived poor acoustic conditions may contribute to a reduced likelihood of perceived recovery from reported voice complaints among teachers.

**Keywords:** recovery; voice complaints; work-related factors; teachers

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## 1 Introduction

Voice disorders represent an important health problem among teachers, with a reported 12-month prevalence between 15% [1] and 80% [2]. Work-related factors include instruction type (e.g. topic of teaching, age of pupils), individual factors (e.g. years of experience, voice use, physiological factors), and physical environment of the classroom (e.g. number of pupils, air quality) all contribute to the occurrence of voice disorders [3]. One of the important environmental factors is the communication environment since teachers will adjust their voice due to their surroundings (e.g. communication intent, classroom noise, reverberation) [4] with indications that poor room acoustics are important associated factors of voice complaints with odds ratio (OR) ranging from 1.8 [5] to 2.7 [6], which would likely reduce the likelihood that a teacher would recover in this environment.
Most previous studies have been cross-sectional designs with little information on associated factors of recovery of voice complaints among teachers. For example, in a previous longitudinal analysis among 480 school workers, self-report of high noise levels was associated with increased incidence of voice complaints, and self-report of poor acoustic conditions was associated with chronic voice complaints [7]. However, the relationship between classroom acoustics and recovery of voice complaints among teachers has not been explored. Most previous studies have used a self-report of physical conditions of the workplaces. Consequently, even when associations between work-related factors and voice complaints have been studied, there has been limited ability to evaluate the influence of classroom acoustics for recovery of voice complaints among teachers. Knowledge about this association is of crucial interest for the design of prevention programs of voice disorders among teachers. Therefore, we

conducted a follow-up study to determine the relationship between classroom acoustics and recovery of already existing voice complaints among teachers**.**

# 2 Methods

This research is part of a longitudinal study with an eleven-month-follow-up, reflecting a full teaching year. Teachers were recruited from 12 public schools in Bogotá, Colombia, in 2012. Baseline assessments were completed during February and March (at the beginning of the school year). Follow-up evaluations were completed during November and December (at the end of the academic year). All teachers in the baseline assessments were contacted again, provided that they were still working in the school. Objective environmental measurements of classroom acoustics were performed in the same period of baseline assessments. Study design and sampling procedures have been described in more detail in previous publications [7-9].

*Study variables*
In addition to sociodemographic variables such as age, gender and level of education, three variables pertinent to this study were included. First, recovery from voice complaints was determined using a detailed questionnaire, with recovery at the end of the academic year characterized in terms of self-report of voice complaints at baseline and no voice complaints at the follow-up [7]. Second, self-reported noise and acoustic conditions was collected by means of a questionnaire where teachers indicated in a categorical scale if they consider comfortable or not the noise levels and the acoustic conditions inside the classrooms. More detailed information on the questionnaire has been presented in previous publications [8, 9]. Third, details about classroom acoustics was collected through measurements of A-weighted sound pressure level, and reverberation time (RT) performed in classrooms. Sound level outside schools was measured as well. Except for reverberation time, all the measurements were performed during actual work activities. RT was measured in non-occupied workplaces during weekends or non-lectures times. All the measurements were performed at three different locations in order to cover the complete classroom. The measurements of sound level outside the schools were targeted at identifying the highest noise level at a distance of 2 meters from walls [10] for each separate school in our sample. The 4 in 1 digital multi-function Environment-Meter Model WK040 was used to measure noise, and the software Room Acoustic Measurement System was used to measure RT. The objective measurements are described in detail in a previous publication [9].

**Statistical Analysis**
Epi-info 3.5.3 (CDC/2011) software was used for data entry; and SPSS 20 software was used for statistical analysis. The multivariate association between recovery of voice complaints at an eleven-month follow-up (outcome variable) and socio-demographics, self-reported noise and acoustic conditions, and classroom acoustics (independent variables) was assessed using multiple logistic regression analysis. Those independent variables with a p-value lower than 0.20 in the univariate analysis were included in the multivariate analyses in order to avoid residual confounding [11], and were only retained if the p-value reached the conventional level of significance of 0.05. All multivariate models were adjusted for sex and age, independent of level of statistical significance, and statistically significant covariates. The magnitude of the associations was expressed as the OR, and the statistical significance as the 95% confidence interval (95% CI).

# 3 Results

## 3.1 Participant characteristics

At baseline, there were 621 teachers in this study. After eleven months, 72% of teachers agreed to continue participating in this research (n=449). Among this population, 323 reported voice complaints at baseline and therefore made up the study population. Approximately 20% of teachers with voice complaints at baseline reported recovery at follow-up.
As shown in Table 1, around 74% of the participating teachers were female and 36% were older than 50 years of age. More than 60% of teachers reported high noise levels and poor acoustic conditions inside their classrooms.

Table 1 Descriptive and determinants of recovery of voice complaints among teachers during an eleven-months-follow-up in 12 public schools in Bogotá D.C., Colombia

| Variable | Descriptive | | Multivariate analysis | |
|---|---|---|---|---|
| | N | % | OR | 95% CI |
| **Socio-demographics** | | | | |
| Female gender | 239 | 74 | 0.73 | (0.39 – 1.37) |
| 50 or more years of age | 115 | 36 | 1.56+ | (0.86 – 2.85) |
| Postgraduate studies | 99 | 31 | 1.00 | Referent |
| High school and Bachelor | 112 | 35 | 0.76 | (0.37 – 1.56) |
| Other levels of education | 112 | 35 | 0.59+ | (0.29 – 1.20) |
| **Classroom acoustics** | | | | |
| High sound level outside school | 73 | 23 | 1.78+ | (0.94 – 3.35) |
| High A-weighted sound level in classroom | 50 | 15 | 1.62+ | (0.77 – 3.43) |
| Large Reverberation Time in classroom | 86 | 27 | | |
| **Self-reported noise and acoustic conditions** | | | | |
| High noise in classroom | 221 | 68 | | |
| Poor acoustics in classroom | 214 | 66 | 0.52* | (0.29 – 0.93) |

* $p<0.05$
+$p<0.20$

## 3.2 Classroom acoustics and recovery of voice complaints

Table 1 also shows the associated factors for recovery of voice complaints (n=65) among all teachers with voice complaints at baseline (n=323). In the univariate analysis, self-reported poor acoustics in the classroom were associated with lower recovery of voice complaints, and this association changed little after adjustment (OR=0.52). High noise levels outside the school and high sound levels inside the classrooms were associated with an increased likelihood of recovery of voice complaints. However, after mutual adjustment these associations were no longer statistically significant.

# 4 Discussion and Conclusions

The current study provides an important addition because (1) it is longitudinal; and (2) it assesses the relationship between classroom acoustics and recovery of voice complaints among primary and secondary school teachers. The main result of this study was that self-reported acoustic conditions inside the classrooms was an important associated factor with recovery of voice complaints at follow-up among teachers.

In previous reports, self-reported high noise levels have been implicated in a higher incidence of self-reported vocal problems [7]. However, in the univariate analysis, teachers who worked in schools with objectively measured high noise levels outside schools and high sound levels inside the classrooms were more likely to recover from their voice complaints. While, after mutual adjustments, these associations only were trending rather than statistically significant, this result is of special interest because it would be expected a dramatic increase in vocal problems rather than a decrease or no statistical change. Since speakers tend to modify their voice levels as a result of their auditory feedback (Lombard effect) [12], it would be expected and has been shown that teachers who worked in noisy classrooms would tend to speak louder. Excessive and prolonged loudness implies an increased vocal loading [13] from increased laryngeal valve resistance to guarantee the production and release of an appropriate level of air pressure. The vocal folds must be adducted strongly to produce the increased medial compression required for this laryngeal resistance. Consequently, the laryngeal mucosa may become irritated and inflamed, which may result in organic voice disorders [14]. Therefore, it would be expected that teachers who worked under noisy conditions would be less likely to recover from voice complaints. However, the increased vocal level is only one part of the response to poor acoustic conditions because people also report discomfort at noisy communication conditions [15] which may give rise to a reduction of speech use and thereby benefit vocal recovery. Another possible explanation for this contradictory result may be that teachers with voice complaints were more aware of their voice use and avoided using excessive or prolonged loudly voice under noisy conditions. A previous study among training teachers suggested that raising awareness may have an effect on voice quality [16]. Future research is recommended to assess the intermediation of awareness of voice use in the relation between classroom acoustics and recovery of voice complaints.

A few limitations of this longitudinal study must be acknowledged. First, there was a considerable dropout (30%) during the follow-up. However, the non-response at follow-up most likely did not bias the findings. Second, the objective measurements only covered a single period of the exposure duration of the study population. Thus, these measurements may be a poor proxy of exposure of teachers who experience variable noise and acoustic conditions during their school year.

In conclusion, this longitudinal study presented some indications that self-reported poor acoustic conditions may be an important associated factor of recovery of voice complaints. Nevertheless, we did not find association between recovery of voice complaints and objective measures of reverberation time at the classrooms. There is a need for longitudinal studies that objectively quantify classroom acoustics repeatedly during the school year. In addition, recent studies have reported speakers´ perspective measures such as voice support ($ST_V$), room gain ($G_{RG}$) and decay time ($DT_{40ME}$) as measures of classroom acoustics. The $ST_V$ indicates to what extent sound reflections at room boundaries amplify the voice of a speaker at his/her own ears [17, 18]. The $G_{RG}$ is the gain applied by the room to the voice of a speaker at his/her own ears [18]. The $DT_{40ME}$ is the time it would take for the backwards integrated energy curve of an oral-binaural room impulse response to decay 60 dB after the arrival of the direct sound, calculated from the initial decay of 40 dB and assuming a linear decay [19]. Future studies are needed to evaluate the relationship between speakers´ perspective measures of classroom acoustics with recovery of voice complaints among teachers.

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