Teachers' Voice Use in Teaching Environments: A Field Study Using Ambulatory Phonation Monitor.

Lyberg Åhlander, Viveka; Pelegrín García, David; Whitling, Susanna; Rydell, Roland; Löfqvist, Anders

Published in:
Journal of Voice

DOI:
10.1016/j.jvoice.2014.03.006

2014

Teachers' voice use in teaching environments:

A field study using Ambulatory Phonation Monitor

Viveka Lyberg Åhlander

Dept. Logopedics, Phoniatrics and Audiology, Clinical Sciences, Lund, Lund University, Lund, Sweden

David Pelegrín García*

Acoustic Technology, Dept. Electrical Engineering, Technical University of Denmark, Lyngby, Denmark

Susanna Whitling, Roland Rydell**, and Anders Löfqvist

Dept. Logopedics, Phoniatrics and Audiology, Clinical Sciences, Lund, Lund University, Lund, Sweden

*also Laboratory of Acoustics and Thermal Physics, K.U. Leuven, Belgium

**also ENT Department, Lund University Hospital, Lund, Sweden

Address editorial correspondence to:
Viveka Lyberg Åhlander
Dept. Logopedics, Phoniatrics and Audiology
University Hospital
SE-221 85 Lund
Sweden
E-mail: Viveka.Lyberg_Ahlander@med.lu.se
Phone: +46 46 177830, Fax: + 46 46 171732

Abstract

Objectives. This case-control designed field-study examines the vocal behavior in teachers with self-estimated voice problems and their age-, and school-matched voice-healthy colleagues. It was hypothesized that teachers with and teachers without voice problems use their voices differently regarding fundamental frequency, sound pressure level and in relation to the background noise.

Methods. Teachers with self-estimated voice-problems (n=14, 2M/12F) were age and gender matched to voice-healthy school-colleagues (n=14, 2M/12F). The subjects, recruited from an earlier study, had been examined in laryngeal, vocal, hearing and psychosocial aspects. The fundamental frequency, Sound Pressure Level, and phonation-time were recorded with an Ambulatory Phonation Monitor during one representative workday. The teachers reported their activities in a structured diary. The sound pressure level (including teacher and students' activity and ambient noise) was recorded with a sound level meter; the room temperature and air quality were measured simultaneously. The acoustic properties of the empty classrooms were measured.

Results. Teachers with voice problems behaved vocally different from their voice healthy peers, in particular during teaching sessions. The phonation time was significantly higher in the group with voice problems and the number of vibratory cycles differed between the female teachers. The F0 pattern, related to the vocal sound pressure level and room acoustics differed between the groups.

Conclusion. The results suggest a different vocal behavior in subjects with subjective voice problems and a higher vocal load with fewer possibilities for vocal recovery.

INTRODUCTION

This paper examines teachers' voice use in their work-environment, exploring the vocal behavior in a group of teachers with self-assessed voice problems (non-patients), comparing them to a group of teachers with self-assessed voice health. This is a follow up study to Lyberg Åhlander et al 2011 and Lyberg Åhlander et al 2012 [1, 2].

One of the most important aspects of teaching is for the teacher to make her- or himself heard. The demands on a teacher's voice are varied. The voice is needed to communicate, instruct and clarify. The teaching tasks at elementary and middle school levels can vary from soft, facilitating talk during morning assembly, to singing, reading loud, lecturing, and teaching in the sports hall. It is thus important for a teacher's voice to be flexible. However, with high levels of BNL and unfavorable room acoustics, this can be an effortful task that may be detrimental to the voice. Recently published data suggest that very few teachers in Swedish schools have undergone any voice training and that voice amplification is rare, even in the schools' sports halls [1]. As pointed out by many authors, teachers are at risk of developing voice problems and there is a high prevalence of voice disorders in teaching staff also when compared to other occupations with vocal demands [3-6]. Teachers' vocal load is also indicated by self-reported sick-leave due to voice problems. In a group of teachers who assess themselves as suffering from voice problems, 35% compared to 9% in a group of voice healthy teachers reported recurring sick-leave due to voice problems [1]. According to Sapir *et al.*, 1993, none in a group with no occupational vocal demands reported sick-leave for this reason [7].

Recent results from comparisons between a group of 31 teachers with self-assessed voice problems and their 31 voice-healthy colleagues indicated that there were no differences between the groups in vocal, laryngeal, hearing or psychosocial aspects. The differences were found in the time needed to recover from voice problems, in the occurrence of voice problems without a concurrent upper air-way infection, and in the subjective assessment of voice symptoms [2]. This leads us to hypothesize that the differences between teachers with and without voice problems might be found in their daily voice use, possibly related to the teaching environment. The differences in teaching environment, other than classroom acoustics, can be in the activity noise produced and in the ability of the teacher to manage and vocally cope with classroom noise. A teacher with voice problems might manage classroom noise less well than a voice-healthy teacher.

During the last decades, a number of research groups have tried to understand teachers' voice use, based on the hypothesis that this behavior might differ from what can be seen in laboratory or clinical settings. e.g. [8-13]. Parameters that have been studied are fundamental frequency (F0), sound pressure level (SPL), and phonation (or speaking) time.
Södersten et al [12] studied the vocal behavior of subjects at their work place and concluded that levels of F0 and SPL differed from the levels measured in quiet environment. Hunter and Titze [14] also studied nonoccupational time and found that the SPL and phonation time of the occupational voice differed from the measurements of the nonoccupational voice. Changes in *fundamental frequency* during a workday have been identified as a sign of voice load. Laukkanen et al [15] described the rise of F0 as a result of an increase in muscular activity, most likely an adaptation to vocal loading during a day at work. In addition, they described that the voice changes during vocal loading include an increase of the SPL and a decrease of jitter and shimmer.. Also Jónsdóttir et al [16] suggests that an F0 increase is a healthy reaction to voice load that promotes effective voice function. However, there seems to be a deviant pattern of the increase of F0 in individuals with voice problems. Rantala et al [10] studied teachers' vocal behavior during a workday, and found a tendency for teachers with many voice complaints to show a smaller increase of their F0 level than their colleagues with fewer

complaints, and Jonsdottír et al [16] found a smaller F0 and SPL increase in teachers with voice complaints when they did not use voice amplification compared to when they did.

The teacher does not act alone in the classroom. Results from an earlier study showed that 92% of the teachers found the activity noise from the students to be disturbing[1]. Thus, it is important to consider the effect of the activity noise on the teacher's voice. The Lombard effect [17] describes the influence of surrounding noise on the voice. The speaker automatically raises the *SPL* and changes the spectral contents of the voice signal as the noise level increases. The BNL in classrooms is usually high, also during instruction, e.g [18-20]. There are a number of studies exploring the effects of noise on vocal behavior, most performed in a laboratory setting: Södersten et al [21] investigated the rise of F0 and SPL due to background noise in healthy subjects. They showed that the speaker increases the SPL and F0 and prolongs the phonation time when exposed to noise, especially continuous noise. In that study, female speakers also reported less success in making themselves heard and greater effort to do so [21]. Ternström et al [22] measured the ratio of energy in the frequency bands 2-6 kHz and .1-1 kHz, and found it to be less negative as a function of increasing BNL and voice SPL. Moreover, Lindström et al [13] showed that there is a large variation in vocal behavior due to noise exposure. Thus, it is important to study voice use outside the laboratory to further understand the vocal behavior and detect possible individual differences in voice use and in the management of vocal load.

Dry air is often mentioned by patients at voice clinics to affect their voices. The dryness of air has been proven to affect vocal prerequisites in laboratory settings, e.g. [23]. However, only one field-study seems to have been made where the effects of air quality and temperature on voice problems have been examined. Rantala et al [24] concluded that poor ambient air quality affected the occurrence of laryngitis in teachers.

One of the factors often mentioned, but seldom studied in relation to the development of voice disorders, is the influence of the room acoustics on the teacher's voice. Pekkarinen and Viljanen [18] concluded that many Finnish classrooms were too reverberant with a resulting reduced intelligibility, which may cause the speaker to use more effort when speaking. Kob et al [25] studied teachers with different voice status acting in different rooms and concluded that teachers with voice problems were more affected by the acoustic properties of the room than their voice healthy colleagues. Lacking a measure describing the speaker's perception of the room acoustics, earlier investigations have used measures that focus on the listeners' perspective, like the reverberation time or the speech transmission index. Brunskog et al [26] and Pelegrín García [27] introduced a measure of *voice support*, linked to vocal intensity variations experienced by an individual talking under different room acoustic conditions. It is a measure based on the two properties of the impulse response defining the airborne acoustic path between the mouth and the ears. These are the direct sound from the mouth to the ears, and the indirect sound from the reflection at the boundaries of the room. Thus, the voice support is the ratio between the energy of the reflected sound (E_r) and the energy of the direct sound (E_d), Equation 1.

$$ST\text{v} = 10\log\frac{E_r}{E_d} \qquad (1)$$

This study is a field study with case-control design. The paper presents the results of the measurements of the teachers' voices exploring the vocal behavior in a group of teachers with self-assessed voice problems and comparing them to a group of teachers with self-assessed voice health. This paper further presents the room acoustics, background noise, and ambient air quality in the two groups' teaching environment. Detailed results on the link between the voice support and the vocal behavior are presented in Pelegrin-Garcia et al [28].

METHODS

Subjects and schools

The subject group of 28 teachers was recruited among participants who had been followed in two previous studies, Lyberg Åhlander et al [1], (a cross-sectional study) and Lyberg Åhlander et al [2] (a case-control design). In Lyberg Åhlander et al [1], teachers at 23 randomly selected schools rated their voices and prevailing voice problems, together with aspects of their teaching environment in a questionnaire. All teachers present at pre-scheduled collegial meetings responded to the questionnaire (n=487). The grouping of teachers with and without voice problems was based on the statements "I have problems with my voice". The division to the two groups was further validated by the answers to the questions on voice symptoms from a Swedish validated version of the VHI (Voice Handicap Index-Throat) [29]. The group with self-assessed voice problems consisted of individuals most of whom without previous contact with any clinical voice care. In Lyberg Åhlander et al, [2] 31 individuals among the teachers with self-assessed voice problems were matched to 31 voice healthy colleagues, for gender, school and as close as possible for age. For the present study, among the 31 pairs, 14 pairs from the schools with the highest frequency of matched pairs were asked to participate. The pairs included 24 women and four men. The demographics of the teachers in the present study are shown in Table 1. As emerges from Table 1 there were no differences between the groups for age or time in occupation, respectively, as shown by a t-test: $t(223) = .579$ and $t(223)=.510$, with $p > .05$ in both cases. Teaching subject varied between individuals as emerges from Table 2.

The teachers worked at three different schools in Lund, teaching primary to high school levels. The schools were approximately equivalent to each other in size, in number of students and staff, and were built during the same decade (mid 1960 to mid-1970). Two schools taught all levels from primary to junior high, and one junior high level. All participants had recently undergone examinations of the larynx, voice recordings and Voice Range Profiling, hearing, and had rated psychosocial aspects as described in Lyberg Åhlander et al, [2] . There were some minor remarks on laryngeal status in both groups but without statistical differences between the groups for any of the above mentioned aspects (for further details, see [2 2].

The subjects were contacted by phone, were informed about the project, and asked if they wanted to participate. Written information was sent by e-mail after the contact was established. Both the teachers and the headmasters of the three schools gave their written consent to participate. The teachers were further asked to identify a "typical" workday on which the APM measurement could be performed. Due to the teachers' schedules and limitations of the APM, it was not possible to record the teachers for more than one day.

Description of the Ambulatory Phonation Monitor (APM) and definition of parameters

Several different methods to study the vocal behavior in the field have been developed during the years, e. g. [30-36]. These devices have used various techniques. The ones in use today are based on accelerometers that estimate fundamental frequency and sound pressure level from skin vibrations produced by the vibrations of the vocal folds. Using this technique, it is possible to track the speaker's voice also in noisy environments without recording the background noise and without privacy intrusions.

The Ambulatory Phonation Monitor (APM) used in this study, made by Kay-Pentax, is a microprocessor based system, estimating the fundamental frequency, SPL, phonation time, and the number of vibratory cycles from skin vibrations captured by an accelerometer that is attached to the front of the subject's neck, above the sternal notch [33, 37]. The software calculates the mode and average of the fundamental frequency in Hz and the mode and average sound pressure level in dB.

Based on these measures, Titze et al [38]and Svec et al [32] have defined the following vocal dose measures:

**The time dose* is defined as the total duration of phonation, i.e., the total cumulated time and the percentage of this time spent phonating.

**The cycle dose* is the total number of vibratory cycles during a period of time. The cycle dose was originally introduced by Rantala and Vilkman [9] as Vocal Loading Index.

Materials

The data were collected with the Ambulatory Phonation Monitor 3200 model 1.04 (APM) (Kay-Pentax, Lincoln Park, NJ). Based on a master thesis, a voice-diary was developed for the teacher to fill-out during the day, to track the activities of the teacher. The diary had two sections. The first consisted of nine questions on general information regarding the teaching situation: the number and grade of the students taught, the teaching activities, the distance from and noise-level of students along with one question on voice hygiene (intake of water during the lesson). There was also a 100 mm Visual Analogue Scale for continuous voice self-assessment where the subjects rated their current voice status (no voice problems - maximum voice problems). The second part consisted of nine questions on voice aspects and one on stress, rated on a categorical scale (not at all; partly; moderately and very much). The voice questions were modified from the VHI-T (Voice Handicap Index-Throat)[29] and from The Voice Symptom Questionnaire [39] (See Tables 7 and 8).

Simultaneously with the APM recordings, the SPL at the teacher's position were measured with a sound level meter (Svantek, model SV-102, Svantek Inc,Warszawa, Poland). The signal was picked up with a lapel microphone at a distance of 15 cm from the teacher's mouth. The sound level meter was placed in the same waist-bag as the APM box. The activity noise levels $L_{N,A,90}$ are defined in this study as the A-weighted, 1-s equivalent sound pressure levels that are exceeded 90 per cent of the time, calculated from the measurements with the sound level meter carried by the teacher. This measure is very weakly affected by the vocalizations of the teacher, which produce much higher sound pressure levels.

The acoustic properties of the classrooms were evaluated with the following acoustic parameters *background noise level (BNL)*, *reverberation time (RT)*, *speech transmission index (STI)*, *sound strength* (G) and *voice support (STv).* These measurements were made while the classrooms were empty. Additionally, the geometrical dimensions of the room were measured. Only the BNL, RT, STI and STv will be presented in this paper. For details on the measurements of the rooms, For details on the measurements of the rooms, refer to Ref[40] .

The ambient air humidity, room temperature and the carbon dioxide (CO_2) contents of the air were simultaneously measured during the work-hours with an indoor air quality measuring device: Q-Trak IAQ Monitor Model 8550 (TSI Inc, Shoreview, MN), analyzed with Trak Pro Data Analysis Software (TSI Inc)

APM-procedure

The data was collected from late January through March 2010. Before the workday started, the APM accelerometer was glued to the subject’s neck with prosthesis glue B-401, Secure Adhesive, just above the sternal notch. The cable, connecting the accelerometer and the APM device, was taped to the back of the neck and thread under the clothes, exiting the garments at waist level. All procedures, including the calibration of the APM followed the manufacturer’s recommendations. The teacher stood or sat in front of the calibration microphone, with the distance guide (15 cm) resting on the upper lip. The subject was then instructed to phonate on the vowel /a/ from the softest to the loudest phonation possible. The APM device was then put in a waist-bag. The APM was worn by the teacher during the workday and preferably also after work hours. The subject was also instructed how to complete the diary, which was supposed to be filled out after each lesson together with the Visual Analogue Scale on current voice status. The journal questions on voice were completed on three occasions: after the first lesson, after lunch and just after the removal of the accelerometer.

Statistics and ethical considerations

The statistical analyses were computed using SPSS 18.1 (IBM, Armonk, NY). For most continuous variables, paired samples t-tests were used. Chi-Square tests were used when parameters where categorical. One way ANOVA was used to compare variations between activities and a standard multiple regression model was used to analyze the influence of the ambient air quality and temperature on F0 and SPL. The alpha level for all statistical analyses was set to .05. The study has been approved by the Institutional Review Board at Lund University (#248/2008).

RESULTS

An overview of the subjects' demographics along with ranges of F0, phonation-time and duration of the recordings is found in Table 2.

Activities and duration-times

The activities during the day were labeled and classified into preparation, teaching, lunch (including private lunch and lunch with the students), meeting, after work, and working out, based on the information in the diary. The data were analyzed by comparisons between work time, time after work and teaching (lessons). There were no significant differences between the teachers with self-assessed voice problems (VP-group) and the teachers with self-assessed voice health (VH-group) for duration of work-time (defined as preparation, teaching, and lunch) during the recorded day as shown by a t-test t(199)=-949 p=.344. Nor were there any differences between the groups for the duration of each activity, shown by a two-way between groups ANOVA $F(3, 184)=0.324$ $p=0.808$ or for the type of activity during work time, shown by a chi-square test for independence $\chi^2(6, n=225)9.87$ $p=0.130$. Due to processing limitations of the APM only a small number of recordings were made for time-off and thus, no further comparisons were made for time outside work.

Phonation-time and number of cycles

There were significant differences between the groups for *percentage of voicing (Time dose)* in particular for teaching, during the work-day as shown by a paired t-test, see Table 3. The VP-group consistently had a higher time dose during all activities.

Further, a one-way ANOVA showed significant differences for Time dose between activities for the VP-group: $F(3.89)= 6.870$ $p=.00003$. Post-hoc comparisons using the Tukey HSD test indicated that the mean scores for all activities differed significantly from "teaching": "teaching" (M=23.6 SD=7.2) differed significantly from the activities "preparation/break" (M=18.5 SD=7.2), "meeting" (M=15.0 SD=8.9) and "lunch" (M=13.5 SD=5.41). The percent of voicing also differed significantly between some of the activities in the VH-group: $F(3,95)=3.550$, $p=.01$. The post hoc test indicated significant differences between "teaching" (M=18.8 SD=8.6) and "preparation/break" (M=13.5 SD=7.2). The effect size, calculated with the eta squared, was 0.20 for the VP-group and 0.11 for the VH-group, showing that the actual difference between activities was small for both groups. The mean Time dose during "teaching", thus ranges between 18 and 24% (SD=7) in this material (Table 3).

There were no significant overall differences between the groups for the *number of cycles* during total work-time or in any specific activity. However for women specifically, the groups differed as shown by a t-test: VP-group: (M=178 765 SD167 063) and VH-group: (M=130 725 SD 100 058), $t(194)=2.487$ $p=0.014$.

F0 and SPL, changes during the day

The results for F0 and SPL as a function of activity and group are shown in Table 4 (female teachers) and 5 (male teachers). Differences in F0 and SPL between activities were assessed with a one-way ANOVA. No significant differences were found for F0 between the groups for the workday or activities, including both males and females. For the measurements of the workday, the SPL values differed significantly for women specifically as shown by a t-test: VP(M=70.0 SD=5.2) and VH (M=74.1 SD=7.8) t(166)= -3.158 *p=0,02*. As emerging from Tables 4 and 5 the results for males and females showed different trends between the groups. For the females Table 4, the VP-group always had lower values for F0 and SPL than the VH-group, but for the males in Table 5, the opposite was the case. The range of the F0 during the work-day emerges from Table 2.

There were no differences between activities for any group or gender as shown by post-hoc comparisons using the Tukey HSD test.

Fundamental frequency and sound pressure level

There was a difference between the groups in the correlation of the inter-play of F0 and SPL during teaching. The correlation for VP was r(104) = -237, and for VH: r(120) = 331, with p< .05 in both cases. Fisher's *r* to *z* transform showed the difference between the groups to be highly significant. As shown in Figure 1, this indicates that the group with voice problems decreases the F0 when increasing the SPL, but the voice healthy group increases the F0 when increasing the SPL.

Room parameters

Activity noise in the class-rooms

An analysis of the pooled results of the measurements of the activity noise during lessons shows that the average A-weighted activity noise level ($L_{N,A,90}$) in classrooms during lessons was 57.2 dB (within a range from 42 dB to 67 dB). The $L_{N,A,90}$ in the two groups did not differ significantly as shown by a two-sample t-test: t(48) = 0.167, p = 0.866. The average measured $L_{N,A,90}$ during the lessons, together with the standard deviation and the range, is shown in Table 6.

Background noise, speech transmission index, reverberation time and voice support

Since many parameters of room acoustics have a strong dependence on the room volume, the rooms were grouped according to the following criteria:

- *Small classrooms* ($V < 100\ m^3$): classrooms for special education or small groups.
- *Medium sized classrooms* ($100\ m^3 < V < 500\ m^3$): regular classrooms, including also classrooms for science and home ed.
- *Sports halls* ($V > 3500\ m^3$): acoustic requirements differ from those for regular classrooms in the building regulations, due to the physical differences with smaller spaces.

The overall mean/maximum A-weighted level of background noise (BNL) in the empty rooms ranged between 32.3 dB/38.5dB (*small classrooms*); 32.7dB/43.5dB (*medium sized classrooms*) and 37.6dB/43.5dB (*sports halls*). The BNL were similar in all rooms, although the overall level in the large rooms was slightly higher than in smaller rooms. Low frequency noise was markedly dominating, all over, indicating that the noise sources could be ventilation or external noise.

The minimum acceptable *Speech Transmission Index* (STI) value according to the Swedish regulation is STI=0.6[41]. All the classrooms fulfilled this requirement. The small classrooms had the highest STI, which is labeled as excellent. The medium classrooms had an average STI rating which is in between “good” and excellent, and the sports halls had an STI rating of good which will decrease in the presence of activity noise. The values for each room category emerge from Table 7.

The *reverberation time* (RT) is highly correlated to the volume of the rooms; those with smallest volumes have the lowest reverberation times. The mean RT in small and medium classrooms did not exceed the regulation for reverberation time in classrooms (0.6 s).

The mean values of *Voice Support* (STv) are shown in Table 7. The only difference between the small and medium sized rooms was that the small classrooms had a slightly higher over-all value. The large classrooms (sports halls) not only had an overall lower value, but the frequency characteristics were qualitatively different, because the low frequencies were predominating. This indicates that the room does not reflect efficiently the high frequencies needed for the speaker's comfort.

For the comparison between the groups, only between-groups statistical comparisons with middle-sized classrooms were meaningful. There were no significant differences between the teaching environments for the VP and VH groups for any of the parameters, STv, STI or RT, shown by independent samples t-tests: STV: $t(23) = -0.86$, $p = 0.399$; STI: $t(23) = 0.21$, $p = 0.834$; RT: $t(23) = -1.36$, $p = 0.187$

Air quality parameters

There were no differences in temperature between the classrooms or for the classrooms for each specific group, the temperature ranging from 19.2°-25.1°C (Median 22°C). Similarly, there were no significant differences between the rooms for the aspects of air-quality or humidity. The mean for air-quality, CO_2 measured in particles/million (ppm) = 687 (SD =143) and for Humidity, in % = 25% (SD=4.3). A standard multiple regression-model did not find any parameter to be significantly contributing to differences in F0 or SPL in any group.

Diary and VAS estimates

There were significant differences between the groups for the following questions as shown by a chi-square test for independence: voice-fatigue; throat-clearing; throat-ache; tenseness of throat; hoarseness; air-loss and stress-level. For female and male teachers there were no differences between the groups for voice changes during speech, difficulties in making oneself heard, or coughing. However, there was a difference between the groups of female teachers, for "teaching" specifically, for the assessment of difficulties in making oneself heard χ^2=(2)6.131 *p*=0.047. The distribution of the answers along with χ^2 and p-values are shown in Tables 8 and 9.

The estimations of voice problems on a VA scale showed significant differences between the groups according to a paired t-test: VP (M=32.3 SD=20.8) and VH (M=11.2 SD=11.8) t(19)=3.441, *p*=.003. A one-way ANOVA showed no differences between teaching-sessions.

DISCUSSION

The teachers' voice use in the classrooms differed between the groups for a number of parameters. The phonation-time differed significantly between the VP and the VH groups and for the female teachers there was a difference between the groups for number of cycles. Further, there was a difference between the groups in the subjective assessments of vocal aspects during the day and also the VAS estimations were significantly higher in the VP-group. Of special interest are the findings of the differences in vocal behavior concerning the levels of fundamental frequency in relation to the Sound Pressure Level. An increase in fundamental frequency has been interpreted as a healthy reaction to voice load in other studies. Laukkanen et al [15], and Jonsdottír et al [16] showed the F0-rise rise to be more evident after voice amplification, unburdening the voice. Rantala and Vilkman [9] found F0 changes to be significant in a group of teachers with few complaints of voice problems but not in the compared group with many complaints. The difference between the groups in the present study thus, confirms that a rise of the F0 can be interpreted as a crucial sign of a healthy voice. We suggest that a rise of F0 should be occurring as a healthy adaption to voice load and that a non-rise of F0 might occur due to voice problems.

A non-occurring F0 rise might reflect a loss of tissue flexibility, a difference in behavior, or of neuro-muscular capacity. Measurements of F0 in relation to SPL during a work day may thus be important for the detection and objective verification of voice problems.

It is essential to point out that these different strategies, or possibilities, of raising the F0 simultaneous with an SPL increase emerged only during field measurements. No differences were detected by the full voice-range profiles (VRP) performed by the same individuals, in Lyberg Åhlander et al [2]. The fact that there were no differences between the VP and VH groups for the VRPs might show that both groups have both the functional and physical means to increase F0 along with increasing SPL in laboratory conditions and without occupational voice load. When comparing measurements, methodological differences need to be considered. Most methods used in clinic and research are based on registrations where the acoustic signal is recorded, but measurements with accelerometer devices are based on mathematical estimations calculated from vibrations transmitted through the skin.

The APM recordings in the present study were made during one ordinary school-day and represent the individual's typical vocal behavior. There was a difference between groups in the subjective assessments of vocal aspects during the day. Also the VAS estimations were significantly higher in the VP-group.

One of the two questions in the diary that separated the groups the most was, not surprisingly, the question about perceived vocal fatigue. The answers to the question of loss of air while talking (*do you have enough air when you talk?*) might of course reflect an insufficient breathing technique. Loss of air during talking may also reflect an underlying functional incompetency of the vocal apparatus or a compensatory behavior to reduce the phonation effort.

We don't know if wearing the APM influenced the teachers' vocal behavior during the day. Apart from some comments on the cables being in the way at some points during the day, the device caused no problems for the subjects. Nor do we know if the measurements influenced the students' behavior. Some of the smaller children reacted when they saw the accelerometer and even told their peers: "better keep the voice low today: Miss xxx has a sore throat". However, the teachers did not note any differences in the behavior of the children. One difficulty in the present study was the matching of the pairs in relation to the groups that the teachers taught. Even if each pair taught the same age groups, it was not possible to control the children's age at the group level. The pupils' age and cognitive level probably affect teachers' vocal behavior. Perhaps more importantly, the measurements were made during a single day, which is a limitation to the study and also of the APM recorder. The APM needs to be recalibrated every day, which logistically prevented long-time measurements. However, Masuda et al [31], concluded that their measurements of 29 subjects over several days did not vary between days within the same subject. The day for the present recordings was selected by the subjects as a "normal" day at work. A newly performed pilot study comparing the voice use during work and leisure in four individuals indicates that the variation between days occurs during the leisure time and not during work time [42]. The fact that the recorded day was the teachers' own choice of day together with the findings by Masuda et al [31], suggest that the chosen day is most likely representative of the subjects' daily pattern of voice use.

Cycle and time doses

The time and cycle doses are two of the potentially most useful measures for understanding the stresses on the tissue of the vocal folds during phonation[32, 38]. There were significant differences between the groups for the time dose and the cycle dose differed specifically between females, in our material with the higher dose in the VP-group. The cycle dose was originally introduced as Vocal Loading Index (VLI) by Rantala and Vilkman, [9] and had a moderate correlation with the voice complaints in their subjects. That is, the more voice complaints, the higher the VLI values. A higher cycle dose in the group with voice problems may thus indicate the usefulness of the cycle dose as a measure of vocal load.

The cycle-dose describes the total number of vibratory cycles of the vocal folds. Since there was no difference between the groups for F0 or SPL the difference in cycle-dose is most likely related to *phonation time*. The percentage of phonation was significantly greater in the voice problem group (24% vs 17%) which confirms the findings by Rantala and Vilkman [9]. Our result of 17-24% of voicing is in line with the findings of others for the teachers' time spent at work. Earlier studies have reported phonation-time in teachers. Masuda et al reported a phonation-time of 20% [31], Titze et al a phonation-time of 23% [15, 43] and in a recent study Hunter and Titze reported phonation-times of 30%, +/-11% [14]. Södersten et al reported a phonation-time of 16.9% in pre-school teachers [12]. To compare: a recently performed study showed that speaking continuously over noise between 3-30 min. gives phonation-times as high as 60-80% [42]. When making comparisons of phonation-time during teaching it is however, necessary to take into account possible differences between countries in teaching methods. In Sweden today, co-teaching is rather common, especially at the elementary and middle school levels. Moreover, there is a general paradigm shift towards a more student-focused teaching style. To teach under such circumstances means less need to lecture in a traditional manner and probably also means more possibilities for vocal rest.

But do the teachers with voice problems really talk more? The answer is probably yes. As shown in Table 2 all the teachers in the VP-group had a low limit of phonation-time range that was higher than the teachers in the VH-group. However, it is important to underline that talking more probably includes less time for pauses and recovery which might start a vicious circle. Further studies are necessary where also qualitative vocal aspects are taken into account.

Recovery

The importance of pausing, both long and short, has been identified in relation to voice recovery after vocal load [43-45]. Short pauses occur during breathing and swallowing. The earlier study by Lyberg Åhlander et al [2] concluded that the subjects with voice problems, also included in the present study, reported significantly longer time periods for recovery after voice load than their voice-healthy colleagues. In the present study, the difference in both cycle and time dose between the groups indicates a difference in vocal load. This may also reflect a difference in the pausing during phonation. The combined results of the differences in estimated recovery times and vocal doses between the VP and the VH groups might indicate that there are changes taking place at a micro-level. This is also hypothesized by McCabe and Titze who developed a conceptual and behavioral model of vocal fatigue and voice recovery [46]. This model describes how phonatory effort, *i.e*. "central fatigue", leads to compensatory functional changes (e.g. greater adduction of the vocal folds), which lead to alterations of neuromuscular processes and changes of the lamina propria (e.g. prevention of a stable blood circulation, and organic micro-changes). These alterations result in non-volitional changes of voice quality, *i.e*. "peripheral fatigue", increasing the phonatory effort, further leading to increased central fatigue, etc. Based on the outcomes of a therapy based on this model, performed in four teachers with vocal fatigue, McCabe and Titze [46] suggest that vocal recovery occurs in two phases. The first, short time recovery, occurs during the first 1-2 hours after voice load as a constant process independent of the rated level of fatigue. The second, long-time recovery takes several days and is hypothesized to correlate to recovery of the lamina propria (*ibid*). The occurrence and distributions of pauses during the day may thus be crucial for the possibility of recovery and the lack of pauses might according to the model contribute to a chronic voice problem.

The high vocal doses measured during lunch need some comments. The lunch-break may be considered to be a time for pause and recovery. Lindström et al [36] observed a decrease in F0 during lunch time. We did not find such a decrease. Instead there were peaks for both SPL and F0 during lunch-time, probably due to a number of teachers having lunch with the children in so called “educational lunches” which might result in higher levels of BNL.

Activity noise and room acoustics

The measured F0 and SPL values also depend on the teachers’ vocal behavior in relation to the room acoustics and the BNL. These aspects were examined for all the subjects in this study by Pelegrin-Garcia et al [28] using a sound level meter and a lapel-mounted microphone. The results showed that both groups were equally affected by noise and behaved in accordance with the Lombard effect [17], increasing their voice intensity with increasing BNL. The values for BNL in this study were very similar to the 56.3 dB reported by Shield and Dockrell [20] in classrooms with quiet pupils and the 56 dB reported by Hodgson [47] and by MacKenzie [19], the latter in acoustically untreated classrooms. The range of measured activity noise levels from 42 to 67 dB is comparable to the range of 40 to 70 dB reported in the study by Hodgson et al[47]. It is noteworthy that the maximum values for BNL in both small and medium sized classrooms exceeded the regulated maximum of 35 dB[48], which probably affects the vocal behavior of both teachers and students.

The room acoustics did affect the teachers’ vocal behavior differently which is shown by the relation between the teachers’ voice SPL and the STv. As mentioned above, the STv is the speaker’s perception of the voice, related to both the direct sound from the mouth to the ears and the reflected sound from the room and is thus, a measure of the assistance that the talker gets from the reflections from the room [26]. The two groups showed opposite trends in their use of the STv. The teachers in the VP-group decreased the SPL of the voice with increasing voice support in the classrooms, whereas the teachers in the VH-group increased the voice SPL.

These results are thus intriguing and needs to be further explored. One possibility is that teachers experiencing voice problems are more attentive to room acoustics out of necessity to preserve their vocal health. Another possibility is that they are too affected by their voice problems to be able to behave differently.

Air quality and temperature

In the clinic, patients with voice problems often mention aspects of the indoor climate in class rooms or offices to be troubling. The most commonly mentioned aspects are “dry air”, “poor air”, and dustiness. One additional factor sometimes mentioned is “bad smell” due to dirty filters in the airshafts. Although there were no differences in temperature between the classrooms of the groups, with temperature ranging from 17.3°-25.1°C, the high temperature in some classrooms is still worth to consideration. The Swedish regulation for indoor work recommends an upper range value of 22°C for teaching environments. There is evidence that mild heat might make the children sleepy and un-focused [49]. Depending on their age, the students may react with more noise due to their need to stay alert, or they may need to be activated, forcing the teacher to be the active part. Both alternatives increase the teacher’s voice load.

The mean CO_2 levels were below the Swedish regulation for indoor work, 1000 ppm, but in a few rooms, the CO_2 level exceeded the stipulated maximum value. The reaction to the CO_2 levels depends on the air humidity and the temperature. Higher temperatures increase the perception of poor air, even though the particles per million values do not exceed the recommendation. The mean humidity estimate was low, 26%, which is normal during winter in Sweden. Air humidity measures are more complicated than the other measures. The level of air humidity is an effect of indoor heating, number of individuals in the room, and the weather. As a consequence, there is no limit value or recommendation for air-humidity in working environment in the Swedish regulation for indoor work.

The present measurements were made during winter, a season during which indoor temperature is regulated by indoor heating, which also may contribute to the perception of air dryness. In an earlier study, teachers with voice problems assessed the class-room air as dry to a significantly higher degree than their voice healthy colleagues did, working at the same schools and during the same season [1]. We can only speculate about the effects of air-dryness on voice and vocal loading in classrooms. It is possible that the origin can be found in the combination of air-way hypersensitivity and vocal loading. Ratings of dry air might be a sign of a generally dryer lower airway mucosa, or a predisposition for this. There were significantly more teachers with allergies and hypersensitivity to strong odors in the group with voice problems in Lyberg Åhlander et al [1]. Thus, the feeling of dryness might be induced by an almost constantly blocked nose. Nasal congestion may originate from allergies or by an easily affected upper airway mucosa, preventing the individual from breathing through the nose, which is essential for moisturizing and warming the inhaled air. Oral breathing might thus enhance the perception of dryness of the inhaled air and might partly explain differences among the groups in having enough air when talking. This line of reasoning is supported by studies of e.g. Sivasankar et al [50] who conclude that oral breathing increased the phonation threshold which, in turn, results in an increased vocal effort. Further studies are required. Intake of water may help in reducing some of the symptoms and is commonly recommended in voice therapy. In the present study, the teachers were asked about their intake of water during teaching. None of the teachers drank water during teaching, which is both remarkable and surprising.

CONCLUSIONS

The APM measurements of two groups of teachers showed that teachers with self-estimated voice problems differed from their age-, gender- and school-matched voice healthy peers in several aspects of voice use, in particular during teaching sessions. The time- and cycle doses were both significantly higher in the group with voice problems. This suggests a higher vocal load with fewer opportunities for vocal recovery during teaching. Moreover, the pattern of F0 changes in relation to both room acoustics and the SPL of the voice differed between the groups, possibly indicating a reduced vocal flexibility in the group with voice problems.

Acknowledgements

This work was supported by AFA-insurance. The authors express their gratitude to Ulf Bergendorf, specialist in occupational hygiene, Lund University, for support and help with the air-quality measurements and to Maria Södersten, Karolinska Institute, Stockholm for valuable comments during the process.

REFERENCES

1. Lyberg Åhlander V, Rydell R, Löfqvist A. Speaker's comfort in teaching environments: Voice problems in Swedish teaching staff. *J Voice*. 2011;25:430-440.

2. Lyberg Åhlander V, Rydell R, Löfqvist A. How do teachers with self-reported voice problems differ from their peers with self-reported voice health? *J Voice*. 2012;26:e149-161.

3. Fritzell B. Voice disorders and occupations. *Logoped Phoniat Vocol*. 1996;21:7 - 12.

4. Roy N, Merrill RM, Gray SD, Smith EM. Voice disorders in the general population: Prevalence, risk factors, and occupational impact. *Laryngoscope*. 2005;115:1988-1995.

5. Smith E, Lemke J, Taylor M, Kirchner HL, Hoffman H. Frequency of voice problems among teachers and other occupations. *J Voice*. 1998;12:480-488.

6. Titze IR, Lemke J, Montequin D. Populations in the U.S. workforce who rely on voice as a primary tool of trade: A preliminary report. *J Voice*. 1997;11:254-259.

7. Sapir S, Keidar A, Mathers-Schmidt B. Vocal attrition in teachers: Survey findings. *Eur J Disord Commun*. 1993;28:177 - 185.

8. Rantala L, Paavola L, Korkko P, Vilkman E. Working-day effects on the spectral characteristics of teaching voice. *Folia Phoniatr et Logop*. 1998;50:205-211.

9. Rantala L, Vilkman E. Relationship between subjective voice complaints and acoustic parameters in female teachers' voices. *J Voice*. 1999;13:484-495.

10. 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.

11. Jónsdóttir V, Boyle B, Martin P, Sigurdardóttir G. A comparison of the occurrence and nature of vocal symptoms in two groups of Icelandic teachers. *Logoped Phoniatr Vocol*. 2002;27:98-105.

12. Södersten M, Granqvist S, Hammarberg B, Szabo A. Vocal behavior and vocal loading factors for preschool teachers at work studied with binaural DAT recordings. *J Voice*. 2002;16:356-371.

13. Lindström F, Waye KP, Södersten M, McAllister A, Ternström S. Observations of the relationship between noise exposure and preschool teacher voice usage in day-care center environments. *J Voice*. 2011;25:166-172.

14. Hunter EJ, Titze IR. Variations in intensity, fundamental frequency, and voicing for teachers in occupational versus nonoccupational settings. *J Speech Lang Hear Res*. 2010;53:862-875.

15. Laukkanen AM, Ilomaki I, Leppanen K, Vilkman E. Acoustic measures and self-reports of vocal fatigue by female teachers. *J Voice*. 2008;22:283-289.

16. Jonsdottír V, Laukkanen AM, Vilkman E. Changes in teachers' speech during a working day with and without electric sound amplification. *Folia Phoniatr Logop*. 2002;54:282-287.

17. Lane H, Tranel B. The Lombard sign and the role of hearing in speech. *J Speech Hear Res*. 1971;14:677-709.

18. Pekkarinen E, Viljanen V. Acoustic Conditions for Speech Communication in Classrooms. *Scand. Audiology*. 1991;20:257 - 263.

19. MacKenzie D. Noise sources and levels in UK schools. International Symposium on Noise Control and Acoustics for Educational Buildings. Istanbul, Turkey: Proc Turkish Acoustical Society; 2000:97–106.

20. Shield BM, Dockrell JE. External and internal noise surveys of London primary schools. *J. Acoust. Soc. Am.* 2004;115:730-738.

21. Södersten M, Ternström 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;Vol. 19:pp. 29–46.

22. Ternström S, Bohman M, Södersten M. Loud speech over noise: Some spectral attributes, with gender differences. *J Acoust Soc Am*. 2006;119:1648-1665.

23. Vintturi J, Alku P, Sala E, Sihvo M, Vilkman E. Loading-related subjective symptoms during a vocal loading test with special reference to gender and some ergonomic factors. *Folia Phoniatr Logop*. 2003;55:55-69.

24. Rantala LM, Hakala SJ, Holmqvist S, Sala E. Connections between voice ergonomic risk factors and voice symptoms, voice handicap, and respiratory tract diseases. *J Voice*. 2012;26:819 e813-820.

25. Kob M, Behler G, Kamprolf A, Goldschmidt O, Neuschaefer-Rube C. Experimental investigations of the influence of room acoustics on the teacher's voice. *Acoustical Science and Technol*. 2008;29:86-94.

26. Brunskog J, Gade AC, Payá-Bellester G, Reig-Calbo L. Increase in voice level and speaker comfort in lecture rooms. *J Acoust Soc Am*. 2009;125:2072-2083.

27. Pelegrín García D. Comment on “Increase in voice level and speaker comfort in lecture rooms”. *J Acoust Soc Am*. 2011;131:194-204.

28. Pelegrin-Garcia D, Brunskog J, Lyberg Åhlander V, Rydell R, Löfqvist A. Influence of classroom acoustics on the voice levels of teachers with and without voice problems: A field study. *Proceedings of Meetings on Acoustics, Vol*. 11, 2010.

29. Lyberg-Åhlander V, Rydell R, Eriksson J, Schalén L. Throat related symptoms and voice: development of an instrument for self assessment of throat-problems. *BMC Ear, Nose Throat*. 2010;10:5.

30. Ohlsson A-C, Brink O, Löfqvist A. A voice accumulator - validation and application. *J Speech Hear Res*. 1989;32:451-457.

31. Masuda T, Ikeda Y, Manako H, Komiyama S. Analysis of vocal abuse: fluctuations in phonation time and intensity in 4 groups of speakers. *Acta Otolaryngol*. 1993;113:547-552.

32. Svec JG, Popolo PS, Titze IR. Measurement of vocal doses in speech: experimental procedure and signal processing. *Logoped Phoniatr Vocol*. 2003;28:181-192.

33. Cheyne HA, Hanson HM, Genereux RP, Stevens KN, Hillman RE. Development and testing of a portable vocal accumulator. *J Lang Hear Res*. 2003;46:1457-1468.

34. Szabo A, Hammarberg B, Håkansson A, Södersten M. A voice accumulator device: Evaluation based on studio and field recordings. *Logoped Phoniatr Vocol*. 2001;26:102-117.

35. Szabo A, Hammarberg B, Granqvist S, Södersten M. Methods to study pre-school teachers' voice at work: simultaneous recordings with a voice accumulator and a DAT recorder. *Logoped Phoniatr Vocol*. 2003;28:29-39.

36. Lindström F, Ohlsson AC, Sjöholm J, PerssonWaye K. Mean F0 values obtained through standard phrase pronunciation compared with values obtained from the normal work environment: a study on teacher and child voices performed in a preschool environment. *J Voice*. 2010;24:319-323.

37. Hillman RE, Heaton JT, Masaki A, Zeitels SM, Cheyne HA. Ambulatory monitoring of disordered voices. *Ann Otol Rhinol Laryngol*. 2006;115:795-801.

38. 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.

39. Simberg S, Sala E, Vehmas K, Laine A. Changes in the prevalence of vocal symptoms among teachers during a twelve-year period. *J Voice*. 2005;19:95-102.

40. Pelegrín-García D, Brunskog J, Lyberg-Åhlander V, Löfqvist A. Measurement and prediction of voice support and room gain in school classrooms. *J Acoust Soc Am*.2012;131:194-204.

41. Swedish Standards Institute. Acoustics - Sound classification of spaces in buildings - Institutional premises, rooms for education, preschools and leisure-time centres, rooms for office work and hotels. Vol SS 25268:2007. Stockholm, Sweden: SIS; 2007.

42. Whitling, S., Rydell, R., & Lyberg Åhlander, V. (2014). Design of a Clinical Vocal Loading Test With Long-Time Measurement of Voice. *Journal of Voice*. doi: 10.1016/j.jvoice.2014.07.012

43. Titze IR, Hunter JE, Svec JG. Voicing and silence periods in daily and weekly vocalizations of teachers. *J Acoust Soc Am*. 2007;121:469-478.

44. Vintturi J, Alku P, Lauri ER, Sala E, Sihvo M, Vilkman E. The Effects of Post-Loading Rest on Acoustic Parameters with Special Reference to Gender and Ergonomic Factors. *Folia Phoniatr Logop*. 2001;53:338-350.

45. Hunter EJ, Titze IR. Quantifying Vocal Fatigue Recovery: Dynamic Vocal Recovery Trajectories After a Vocal Loading Exercise. *Annals Otol Rhinol & Laryngol*. 2009;118:449-461.

46. McCabe D, Titze I. Chant therapy for treating vocal fatigue among public school teachers: a preliminary study. *Am J Speech-Language Pathol*. 2002;11:356-369.

47. Hodgson M. UBC-classroom acoustical survey. *Canadian Acoustics*. 1994;22:3-10.

48. Arbetsmiljöverket. AFS 2009:02 Arbetsplatsens utformning [Work place design]. Stockholm 2009.

49. Hygge S. The interaction of noise and mild heat on cognitive performance and serial reaction time. *Environm Internat*. 1991;17:239-244.

50. Sivasankar M, Erickson E, Schneider S. Phonatory effects of airway dehydration: Preliminary evidence for impaired compensation to oral breathing in individuals with a history of vocal fatigue. *J Speech Lang Hear Res*. 2008;51:1494-1507.

Figure captions

FIGURE 1. Relationship between sound pressure level and F0, averages across all activities and subjects; n=14 matched pairs.

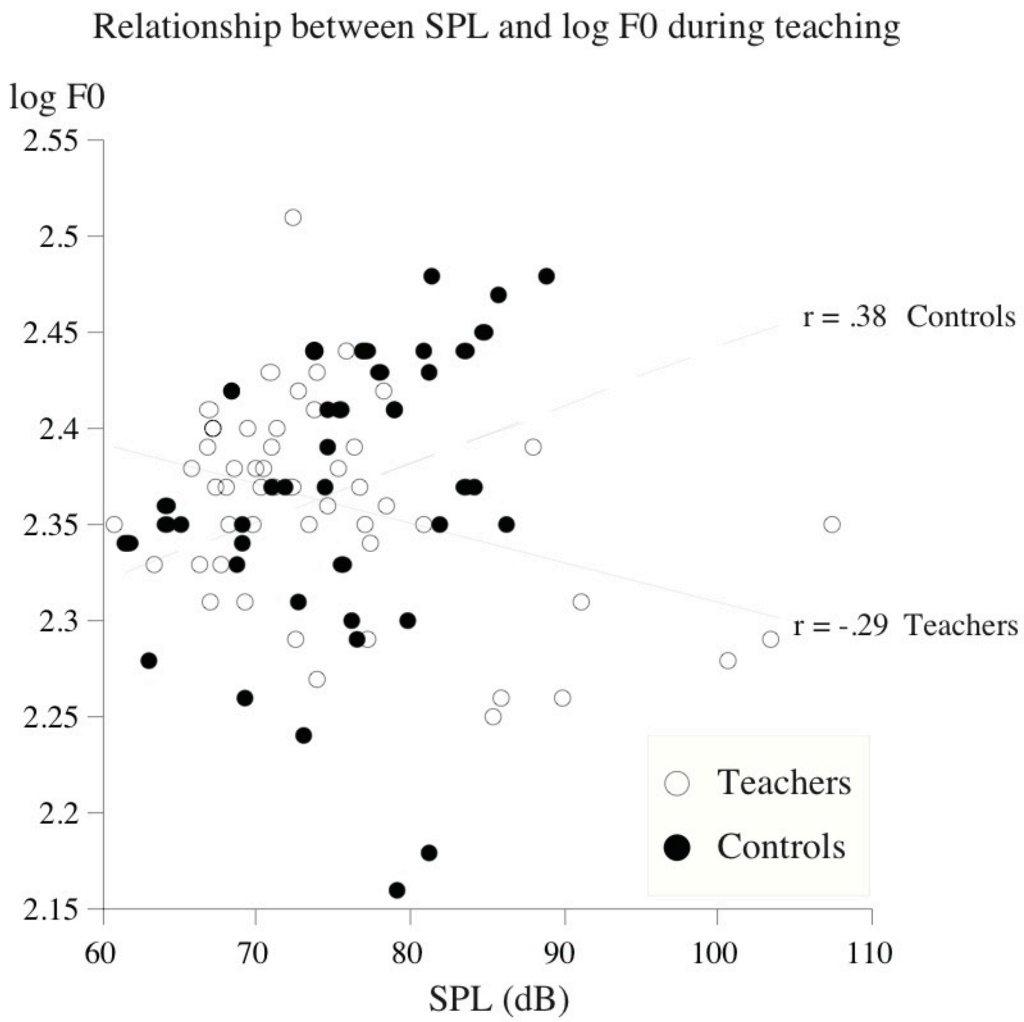

Table 1. Distribution of gender, age and time in occupation of n=28 teachers. VP= teachers with voice disorders. VH = teachers without voice disorders.

Group	**Gender F/M**	**Age** **Median (range)**	**Time in occupation,** **Median (range)**
VP, n=14	12/2	41 (24-62)	13 (2-40)
VH, n=14	12/2	43 (28-57)	18 (2-28)

Table 2. Demographics of n= 14 teachers with voice problems (T) and n=14 voice healthy teachers (C) along with age; gender; age and number of their students; subject taught; duration of the measured time; range of F0 means and the range of percentages of phonation-time during the workday.

Id	Age	Gender	Age students	Subject	No students	Total time measured Hrs:min.	F0 Hz Range of means	Phonationtime % Range
T1	29	F	16-19	Swedish/English	30	1:45	204-231	24.1-29.7
C1	28	F	6-15	Elementary school teacher	20	6:4	216-256	0.45-15.0
T5	54	M	12-15	Sports	30	5:10	151-226	7.5-24.0
C5	51	M	12-15	Science	30	8:53	132-153	10.6-42.4
T6	62	F	12-15	Science	2-20	6:12	213-233	3.5-29.6
C6	47	F	12-15	Swedish/English	25-30	6:20	199-233	6.0-22.2
T8	57	F	12-15	Remedial teacher	1-6	5:19	213-224	5.7-18.4
C8	56	F	10-15	Home education	15	8:48	241-273	10.0-34.5
T20	54	F	5-9	Elementary school teacher	25	8:32	219-268	17.8-29.0
C20	47	F	5-9	Elementary school teacher	25	8:47	190-256	8.3-22.3
T21	34	F	5-9	Remedial teacher	1-4	5.48	226-262	12.7-32.0
C21	36	F	12-15	Swedish, French, English	25	8:20	218-261	1.3-27.2
T22	37	F	12-15	Swedish/English	25	6:45	215-266	9.2-29.6
C22	32	F	5-9	Elementary school teacher	25	9:15	191-275	8.3-33.6
T23	37	F	5-9	Elementary school teacher	30	7:25	208-325	8.3-30.2
C23	35	F	5-9	Elementary school teacher	25	7:16	223-242	12.1-26.2
T24	47	F	5-12	Elementary school teacher	20	8:15	207-281	13.0-34.0
C24	51	F	10-12	Sports	25	7:20	216-304	11.3-26.3
T26	39	F	5-9	Elementary school teacher	20	2:39	181-196	15.0-35.8
C26	34	F	5-9	educator	20	6:30	223-270	7.0-24.6
T28	57	F	5-9	Elementary school teacher	25	5:39	210-283	8.4-39.0
C28	56	F	5-9	Elementary school teacher	20	5:50	211-256	5.8-24.7
T29	47	F	9-12	Elementary school teacher	20	6:30	215-235	8.9-31.2
C29	43	F	6-8	Educator	40	5:29	206-264	1.9-25.0
T30	24	M	9-15	Sports	20	8.39	135-222	6.5-26.0
C30	43	M	5-12	Educator	20	5:49	171-193	2.4-13.5
T31	40	F	12-15	Social Science	30	4:47	211-231	23.0-31.9

C31	41	F	5-9	Elementary school teacher	25	9:18	255-301	9.2-27.4

TABLE 3. Time dose in %, across activities in two groups of teachers: VP-group, n=14 teachers with voice problems and VH-group n=14 voice healthy teachers

Time dose %	VP Mean(Sd)	VH Mean(Sd)	t(df)	p
Workday	20.9 (8.1)	15.5 (8.0)	4.870 (87)	0.006
Teaching	23.6 (7.4)	18.2 (8.7)	3.023 (97)	0.003
Meeting	16.6 (8.6)	14.8 (5.6)	539 (17)	NS
Preparation/break	17.9 (7.0)	14.0 (7.2)	2.025 (50)	0.048
Lunch	16.6 (7.9)	14.3 (4.6)	858 (20)	NS

Table 4. Mean values of F0 and SPL for activities during a day for two groups of female teachers: VP, n=12 teachers with voice problems and VH n=12 teachers with healthy voices. N denotes number of measured sessions.

Activity (measured sessions)	**F0 Hz (Sd)**	**SPL dB (Sd)**
Work-day		
VP (n=79)	233.5 (24)	70 (8)
VH (n=89)	240.1 (26)	74 (7)
Break/Planning		
VP (n=21)	226 (17)	67 (14)
VH (n=24)	235 (23)	72 (8)
Teaching		
VP (n=46)	237 (25)	71 (5)
VH (n=41)	245 (29)	75 (7)
Meeting		
VP (n=5)	224 (16)	66 (2)
VH (n=11)	233 (31)	73 (7)
Lunch		
VP (n=7)	241 (35)	69 (7)
VH (n=13)	235 (22)	75 (9)

Table 5. Mean values of F0 and SPL for activities during a day for four male teachers from two groups: VP, n=2 teachers with voice problems and VH n=2 teachers with healthy voices. N denotes number of measured sessions.

Activity	F0 Hz (Sd)	SPL dB (Sd)
Work-day		
VP (n=14)	178.2 (29.3)	79.6 (8.4)
VH (n=10)	159.5 (21.3)	75.6 (6.0)
Break/Planning		
VH (n=5)	170 (17)	87 (10)
VH (n=2)	136 (6)	70 (4)
Teaching		
VH (n=7)	194 (25)	95(9)
VH (n=5)	169 (20)	76 (5)
Meeting		
VP (n=1)	-	-
VH (n=2)	153 (25)	76 (8)
Lunch		
VP (n=1)	-	-
VH (n=1)	-	-

Table 6. The average measured $L_{N,A,90}$ during the "teaching", together with the standard deviation and the range for the groups of teachers with self-assessed voice problems (VP) and voice healthy teachers (VH).

Group	Lessons with valid data	Mean value (dB)	Standard deviation (dB)	Minimum (dB)	Maximum (dB)
All	50	57.2	6.1	42	67
VP	20	57.4	6.0	42	66
VH	30	57.1	6.2	45	67

Table 7. Comparison of mean (sd) values of overall Acoustic Voice Support, Speech Transmission Index and Reverberation time in three categories of classrooms.

Room Acoustics and Room Acoustic measures			
	VH	**VP**	**All**
Small classrooms			
n	1	2	3
ST_V [dB]	-6.5 (-)	-5.2 (0.28)	-5.6 (0.78)
STI	0.78 (-)	0.81 (0.014)	0.80 (0.02)
$RT_{500\text{-}2k}$ [s]	0.37 (-)	0.32 (0.04)	0.34 (0.05)
Medium classrooms			
n	15	13	24
ST_V [dB]	-10.5 (1.35)	-10.0 (1.68)	-10.2 (1.58)
STI	0.75 (0.03)	0.75 (0.02)	0.75 (0.03)
$RT_{500\text{-}2k}$ [s]	0.44 (0.07)	0.48 (0.07)	0.46 (0.08)
Sports halls			
n	1	2	3
ST_V [dB]	-17.7 (-)	-19.3 (0.57)	-18.8 (1.01)
STI	0.62 (-)	0.64 (0.01)	0.63 (0.02)
$RT_{500\text{-}2k}$ [s]	1.54 (-)	1.48 (0.23)	1.50 (0.23)

Table 8. The result of Chi-square test for independence of the diary-questions in two groups of teachers: VP: teachers with voice problems (n=14), VH: teachers without voice problems (n=14). Distributions are presented in %. Chi-square values, degrees of freedom and p-values are also provided. Number of answers: VP: n=42, VH: n=43.

Question	No (%)	Partly (%)	Moder (%)	Much (%)	χ^2 (Df)	*p*
Do you perceive voice fatigue? VP VH	29 58	48 40	19 2	5 0	12.245 (3)	0.00 7
Does your voice break or tire? VP VH	64 86	29 12	5 2	2 0	5.757 (3)	0.12
Do you have difficulties in making yourself heard? VP VH	67 74	29 23	5 2	0 0	0.770 (2)	0.68
Do you have a need to clear your throat? VP VH	31 44	36 46	17 9	17 0	9.647 (3)	0.02
Do you have a need to cough? VP VH	57 79	26 14	12 7	5 0	5.684 (3)	0.12
Does your throat ache? VP VH	52 81	33 16	9 2	5 0	9.088 (3)	0.03
Is your throat tense? VP VH	38 70	43 28	17 2	2 0	10.951 (3)	0.01
Do you have a hoarse voice? VP VH	67 77	14 21	19 2	0 0	6.443 (2)	0.04
Stress-level VP	Low 45	Rel.low 31	Rel.high 19	High 5	8.522 (3)	0.04

VH	35	58	7	0		
Do you have enough air when you talk?	Always	Nearly always	Almost never	Never		
VP	52	45	2	0	9.907(2)	0,007
VH	84	16	0	0		

TABLE 9. Distribution of assessment of “difficulties in making oneself heard” in N= 24 female teachers, for the aspect of “teaching”.

Do you have difficulties in making yourself heard?	No (%)	Partly (%)	Moder (%).	χ^2 (Df)	*p*
VP VH	38 36	21 2	0 2	6.131 (2)	0.047