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Voice Changes During Work: Subjective Complaints and Objective Measurements for Female Primary and Secondary Schoolteachers

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Summary: The purpose of this investigation was to study voice changes during a working day. The subjects consisted of 33 female primary and secondary schoolteachers who recorded their first and last lessons during one school day. The subjects were studied both as one group and two subgroups (those with many and those with few voice complaints). Estimates of fundamental frequency (F_0), sound pressure level (SPL), the standard deviations of these values (F_0 SD; SPL SD) and F_0 time (vibration time of vocal folds) were made. The most obvious change due to loading was the rise of F_0 that was 9.7 Hz between the first and last lesson (P = 0.00). F_0 increased more (12.8. Hz, P = 0.006) in the subgroup with few complaints. **Key Words:** Loading—Warm-up—Working environment—Female teacher.

INTRODUCTION

The occupational health care of professional voice users is surprisingly undeveloped compared, for instance, to the attention given to occupational hearing disorders or many other occupational symptoms. However, there are a growing number of persons whose professions set great demands on both the quality and quantity of voice, and from their perspective, the inadequate occupational voice care is a great disadvantage. For example, the voice disorder of a professional voice user is not accepted as an occupational disease by insurance companies in most European countries.[1]

The only way to develop occupational health in voice professions is to demonstrate the relationship between voice problems and voice usage. The evidence reported so far, however, has not been convincing. One reason for this has been the small number of loading studies, which only increased during the past 10 years. Furthermore, these studies have suffered from the problem of small study groups, which has led either to inconsistent results between the studies[2–4] or to the conclusion that speakers react highly individually to loading.[5,6]

In addition, evidence of the relationship between loading and vocal fatigue is also needed from studies arranged in real working situations, instead of laboratory settings, where most of them have been done.[5,7,8] Although lab settings have many advantages, including the possibility to control variables, the question of how to generalize the results outside the lab remains open. For instance, it has been found

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that the values of F_0 depend on the circumstances: they are lower in *reading* samples in a lab than in teaching speech in a classroom.[9] The difficulty of simulating a real-life situation in a lab, and of understanding the clinical implications of laboratory results has perhaps been realized recently, which is indicated by the latest loading studies that have used talking at work as loading.[2,10]

Apart from the contradictory results of loading studies, the definition of “fatigue due to loading” is far from consensual. The disciplines that have most extensively studied loading effects are sport and exercise physiology[11,12] and occupational ergonomics.[13] According to researchers of these fields, the term “fatigue” has been used in so many different senses that its application has become almost meaningless. Enoka[11] gives, however, one definition of fatigue. He points out that fatigue is not a single event, but rather a series of adaptations that occur during sustained activity (loading), and these adaptations begin immediately after the onset of effort. In this paper, we use Enoka’s definition of loading and its effects.

In the area of vocology, only a few researchers have made attempts to understand the physiological background of vocal fatigue. Scherer et al[14] and Titze[15,16] have speculated most on the issue. They propose that vocal fatigue may emerge in any component of voice production, a view that is in is in accordance with that proposed in sport physiology[12] and occupational ergonomics.[13] Stemple, Stanley, and Lee[3] (see also Eustace, Stemple, and Lee[17]) and Vilkman et al[8,18] (see also Lauri et al[19]) have also given explanations of loading changes. Stemple et al hypothesize that fatigue of the thyroarytenoid muscle underlies the changes, whereas Vilkman et al consider changes due to voice loading to be caused by compensation by the speaker for alterations in voice.

The need to develop a more extensive understanding of voice changes during loading in real speaking situations, and the need to develop occupational voice care have motivated this study. In order to improve occupational rehabilitation, the association between voice problems and voice usage has to be proved at both scientific and individual levels, according to the Finnish legislation on occupational diseases. For this purpose, an appropriate method is needed. Thus, a major long-term goal of this work has been to develop methods for collecting and analyzing voice samples produced in natural situations. To the best of our knowledge, only two voice loading studies have so far measured voice during work.[20,21] The reason for this is probably the abundance of practical and technical problems involved in field studies.[22] We have previously published results on the method used in these studies,[22,23] the relationship between subjective complaints and the acoustic variables recorded during a working day,[24] and the spectral changes that occur during a working day.[25] A voice recording method of this kind has the potential to increase the clinical resources needed to diagnose voice problems, to plan and follow up voice therapy, and to improve working circumstances.

The main aim of the present study was to examine the effects of voice loading in a vocally demanding profession during one working day. Because the environment of a workplace cannot be controlled, and the changing circumstances also probably affect voice, not all the changes that take place during a day can be interpreted to be caused by loading. Therefore, the first objective of the present study was to find out what features of voice change during a single working day. The second aim was to compare the speakers who have many voice complaints to those who have few complaints and to study if their voices change in different ways. Originally, we also aimed to recruit one study group without any voice complaints, but no such participants could be found among teachers.

In order to quantify the phonatory features of voice, five variables were chosen. The first one, F_0, seems to be one of the most sensitive parameters to indicate changes, although the results have not always been consistent with each other. F_0 has mostly increased due to loading[3,8,20] (tendency[26,27]), but it has also decreased (tendency[28,29]) or remained unchanged.[5,21] (The term *tendency* refers to results that are not statistically significant—very probably due to the small number of participants—although the variables have changed, or to results on which significance tests have not been made because of the small number of participants.) The second variable measured was sound pressure level (SPL). It has been less commonly used than F_0 in loading studies, although there is evidence to suggest that loading raises its value[8] (tendency[26,27,30]). This variable, however, has shown contradictory results similarly to F_0.[5]

Furthermore, the standard deviations of F_0 (F_0 SD) and SPL (SPL SD) were measured. It appears that, so far, SPL SD has not been investigated as an independent parameter in any voice studies. Likewise, only a few voice studies have been made on F_0 SD. The aim of these studies has been to investigate the association of F_0 SD either with the instability of phonation[31,32] or with voice disorders.[33] Also, neither of these variables has been measured independently in loading studies. Apart from the acoustic measures, the active vibration time of the vocal folds (F_0 time) was measured. It has been shown that professionals who have frequent voice problems—such as teachers—have to speak longer at work than those who have fewer voice difficulties.[34,35]

METHOD

Participants and questionnaire study

The participants consisted of 33 female primary and secondary school teachers. The participants' mean age was 43 years (range 33 years), and the mean number of teaching years was 17 (range 28 years). Prior to the recordings, the participants completed a questionnaire with nine statements concerning voice fatigue symptoms (questionnaire in Appendix A). The statements were based on the questionnaires presented in the literature.[21,36,37] The participant's propensity to vocal fatigue problems was evaluated using the following categories: (1) less than once a year; (2) a few times per year or relatively seldom; (3) once a month or relatively often; (4) almost every week or very often. The scores of each participant were summed up as a sum variable of voice complaints (for the scoring of the questionnaire, see Appendix B). At the time of the study, each participant's voice represented her normal voice.

Based on the voice complaint scores, the participants were divided into two subgroups: the half with lower scores was called the FC group (few complaints; mean of scores 6) and the half with higher scores the MC group (many complaints, mean of scores 31). There were 16 participants in the FC group. Their mean age was 41 years (range 29 years) and their mean number of teaching years 15 (range 26 years). The MC group consisted of 17 participants, whose mean age was 45 years (range 28 years) and mean number of teaching years 18 (range 26 years). The groups did not differ from each other according to the grade level.

Some participants had experienced symptoms of voice disorders, but were capable of working at the time of the study. A stroboscopic evaluation was offered to the participants, but only 20 teachers could find suitable time for it. However, those who had the most problems with voice usage attended the evaluation. The examination revealed that two of the participants had small incomplete posterior closure, which is a normal laryngeal status in females.[38] In addition, one had significantly incomplete posterior closure and one small incomplete anterior closure. Because these two teachers were capable of working, they were included in the study group.

Recording samples

The participants were asked to record their first and last lessons on a normal working day. They used a portable battery-operated digital audiotape (DAT) recorder (Sony TCD-D3, Sony, Tokyo, Japan) on a belt strap. A head-mounted omnidirectional condenser microphone (AKG C567E1, AKG Acoustics, Vienna, Austria) was located on one side of the mouth at a distance of 6–8 cm from the lips. The recorder was light (700 g) and permitted the participants to walk freely in the classroom. The recording level was adjusted individually and kept constant. A calibration signal was recorded for a comparison of the absolute sound pressure levels [a sine wave of 200 Hz at an intensity of 80 dB SPL (A)].

The average duration of the lesson was 35–45 min, and the mean length of the school day was 5 hours (range 3–6). The participants also had lessons between the recording periods (i.e., between the first and last lessons). The number of pupils in attendance varied from 20 to 30. The acoustics of the classrooms were quite similar due to the identical furnishings: a larger desk for the teacher, desks for the pupils, and no textiles on the walls. Both oral and written instructions for using the tape recorder and performing the vocal tasks were given to the participants in advance.

Acoustic analysis

Because it is plausible that teachers' voice usage may vary in the course of a lesson, three different time points from both lessons were taken for analysis: the first, middle, and last four minutes (T1–T3 for the first lesson; T4–T6 for the last lesson). Only speaking voice was accepted for analysis, and the possibility of singing or reading a text by the participant was rejected due to the influence on F_0.[9,20] F_0, F_0 SD, SPL, SPL SD, and F_0 time were analyzed. In the SPL analysis, one participant's data were excluded due to the exceptionally high values, which indicated that the adjustment of the SPL level had obviously changed after the initial setting.

F_0 and SPL were measured with an analogue system (F-J Electronics, Vedbaek, Denmark), and the analysis was made with a microcomputer (Apple Macintosh Quadra 950, Cupertino, Canada) equipped with three extension boards (National Instruments). The digital speech-processing functions were provided by software blocks custom-built and implemented using a LabVIEW 2 graphical programming system (National Instruments, Austin, Tex). Three different signals were used in the analysis: the SPL signal with integration time of 10 ms, the F_0 signal, and the audio signal. The sampling rate for each signal was 5 kHz. The program calculated the F_0 time from the F_0 signal. The margin of error of the analysis program was only 0.4%–0.5%, of which the majority was due to the irregularities typically found in F_0 at the beginning of utterances.

Because the background noise between the participants' speech sequences in the recordings might have distorting effects on the measuring of the SPL signal, it was deleted manually with an editing program. In the program, the signal was read from the hard disk to the computer RAM in chunks of 60 seconds. Deletion of noise was performed with the help of both the graphical display of signals on the computer screen and the audio signal that could be heard through headphones. Since the distance between the microphone and the lips in the recordings was short and the speech signals were thus clearly stronger than the background noise, noise simultaneous with the teacher's speech did not require any erasing.

Statistical analysis

The values for the variables are presented as arithmetic means and standard deviations. The change between the first and last lesson was analyzed with Student's *t*-test for paired samples. The variable changes across the measured time points were tested with repeated measures analysis of variance. Student's *t*-test for paired samples was performed as a post hoc test to evaluate the changes in more detail. The compared points of time were corresponding parts of the lessons (i.e., T1–T4, T2–T5 and T3–T6). Furthermore, because vocal warm-up has been shown to take place during the first 10–30 minutes of talking,[14,39,40] the time interval T1–T2 was also analyzed.

The differences in the variable values between the FC and MC groups were studied by the between-subjects approach of the analysis of variance. The changes in the variables in both groups were tested by Student's *t*-test for paired samples, and the differences in the variable changes between the subgroups were studied with the *t*-test for independent samples.

Because the variation of F_0 has been shown to be related to SPL,[41,42] their interaction was illustrated by r^2 computed from a correlation analysis (Pearson's r). The alpha level of 0.01 was adopted for the test results due to the many statistical computations performed for the variables. The Statistical Program for Social Sciencs (SPSS) was used in the analysis.

RESULTS

Changes in the whole group during one working day

The mean F_0 (pooled over the values of the separate recording periods) for the last lesson was 9.7 Hz higher than for the first one (t = -3.68, df = 32, P = 0.00). Table 1 shows the mean values of F_0, F_0 SD, SPL, SPL SD, and F_0 time for the three voice samples of the first and last lessons. The repeated measures analysis of variance confirms the same result: F_0 changed across the working day [F = 6.5 (1,31), P = 0.00].

Since there were changes in the objectively measured variables, the comparisons were computed as post hoc tests between the corresponding periods of the lessons (Table 2, see column "whole group"). Of the variables, F_0 and SPL SD changed. The alteration of F_0 was unidirectional: its average value increased between all analyzed time intervals except during the period of possible vocal warm-up (T1–T2). The change that took place during the period of vocal warm-up was the decrease of SPL SD.

TABLE 1. *Mean Values and Standard Deviations of Variables Measured in Three Different Periods of the First and Last Lessons (N = 33)*

	First lesson				Last lesson			
	T1	**T2**	**T3**	**M**	**T4**	**T5**	**T6**	**M**
F_0 (Hz)								
M	232.6	229.2	233.3	231.7	240.9	240	243.3	241.4
SD	27.4	25.2	27.5	25	20.1	31.5	30.3	29.2
F_0 SD (Hz)								
M	54.4	53.5	54.4	54.1	56.6	55.9	56.8	56.4
SD	9.3	9.4	8.3	7.8	9.8	10.1	10.7	9.6
SPL (dB)								
M	77.6	77.2	77.8	77.5	77.7	77.9	78.5	78
SD	4.9	5.6	4.6	5	5.1	5.9	5.8	5.6
SPL SD (dB)								
M	7.4	6.8	7.3	7.2	7.5	7.2	7.4	7.4
SD	2.4	2.4	1.8	2.1	2.3	2.2	2.2	2.2
F_0 time (sec)								
M	81	80.8	79.9	80.6	82.1	77.4	76.4	78.6
SD	24.4	27.1	26.5	20	22.2	34.4	30.6	23.4

Note. T1 = beginning; T2 = middle; and T3 = end part of the first lesson; T4, T5, T6, respectively, for the last lesson.

TABLE 2. *Statistically significant voice changes (paired* t*-test) in teachers' speech during a working day. Corresponding periods of the first and last lessons are compared with each other, and the vocal warm-up period (T1–T2). In the whole group,* N *= 33 for the other variables but N = 32 for SPL and SPL SD; in the subgroup with few voice complaints (FC)* n *= 16 for the other variables, but* n *= 15 for SPL and SPL SD; in the group with many voice complaints (MC),* n *= 17.*

	Changed variable		
Period	**Whole group**	**FC group**	**MC group**
T1–T2	-SPL SD*	-SPL SD*	
T1–T4	+F0**		+F0 SD*
T2–T5	+F0**		
T3–T6	+F0**		

Note. Recording periods: T1 = beginning, T2 = middle, and T3 = end of the first lesson; T4, T5, T6, respectively for the last lesson. + indicates that the value has increased; – indicates that the value has decreased.*$p \leq 0.001$, **$p \leq 0.01$.

Differences between the FC and MC groups

The F_0 rose 12.8 Hz (t = -3.17, df = 15, P = 0.006) between the average of the first and the average of the last lessons in the FC group. Similarly, the MC group's F_0 increased, but the rise was less than that for the FC group, only 6.8 Hz. It was not statistically significant. The curves of the separate variables for the FC and MC groups are presented in Figure 1. Although the curves show that the values of the variables were generally higher in the MC group, the repeated measures analysis of variance (between subjects) failed to differentiate the subgroups from each other. Also, the curves suggest that the patterns of change for SPL SD and particularly F_0 SD appear to be parallel to the curves of SPL and F_0. Therefore, the associations between the changes in the individual scores of these variables were computed with a correlation analysis separately for the different periods. According to the analysis, no significant relationships were found between the changes of SPL and SPL SD, whereas the F_0 changes correlated with the F_0 SD changes (for the different periods, r^2 ranged from 0.32 to 0.58, P = 0.001–0.000). In addition, the relationship between the SPL change and the F_0 change was computed. The r^2 values of the corresponding time periods varied from 0.09 to 0.3 (P = 0.08–0.001).

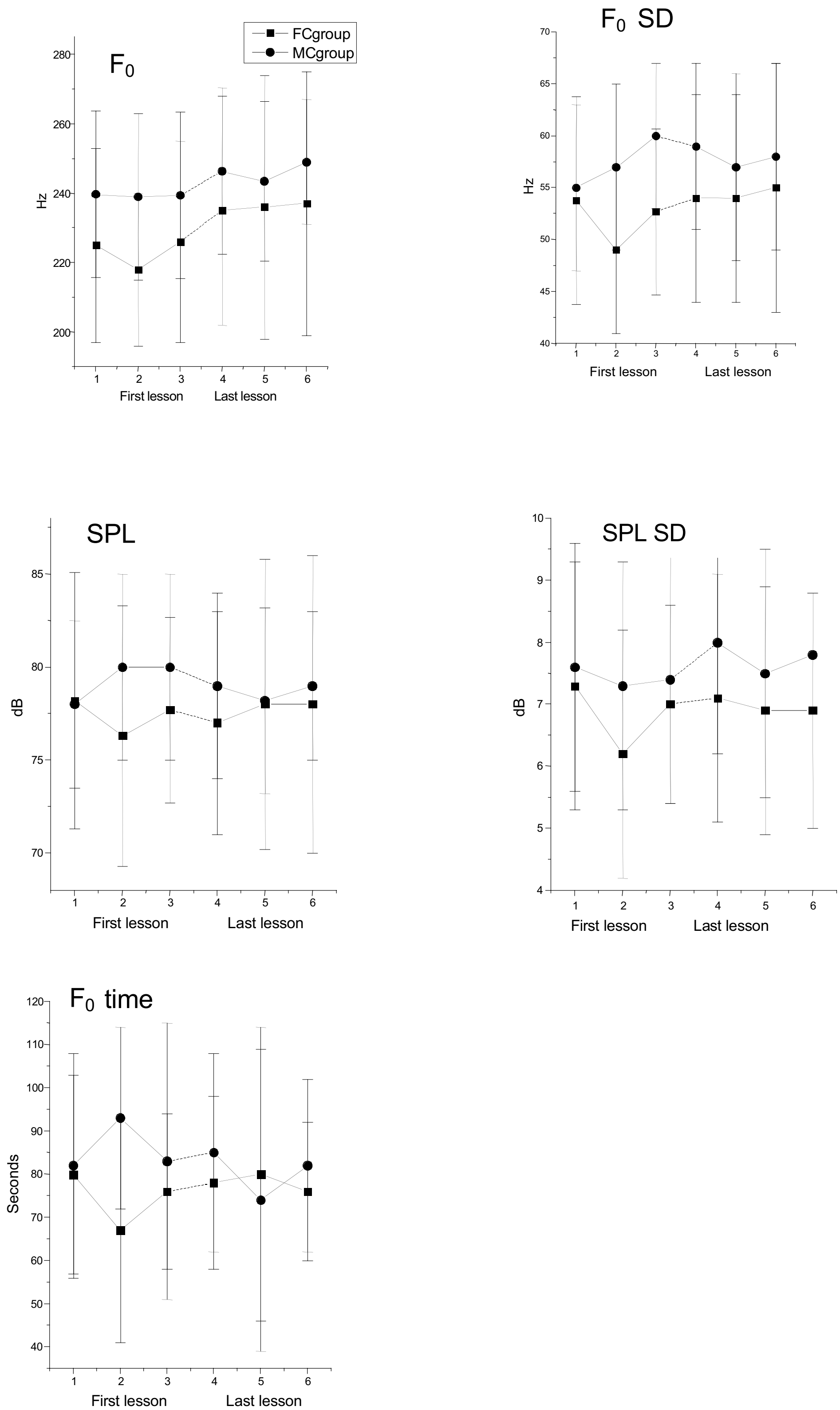

FIGURE 1. Curves for the variables (SD in bars) in the group with few voice complaints (FC; $n = 16$) and in the group with many voice complaints (MC; $n = 17$). 1 = beginning, 2 = middle, and 3 = end of the first lesson; 4, 5, 6, respectively, for the last lesson.

Table 2 presents the periods during which the changes of the variables took place within the two groups (see the columns "FC group" and "MC group"). Two significant changes happened: F_0 SD rose for the FC group and SPL SD decreased for the MC group. Also studied were different changes in the subgroups during the day. The changes between the corresponding points of time of the two lessons were compared with each other. According to the analysis, F_0 time during the period T2–T5 separated the subgroups. It increased 12.9 seconds for the FC group but decreased –18.6 seconds for the MC group (t = -3.18, df = 16, P = 0.008).

DISCUSSION

Voice changes

The results showed that some voice features changed during the working day. The changes were not, however, monotonic. They were not the same during every period and in all the variables, and the changes were different in the subgroups. The most obvious and uniform changes were seen in F_0: it increased toward the end of the working day, and it changed both in the whole group and in the FC group.

As to the interpretation of the changes that emerged in uncontrolled, natural circumstances, many reasons may have caused the alterations in the variables. First, laryngeal adjustments (e.g., the interaction between SPL and F_0[42]) may affect the features of voice. Indeed, the changes of mean F_0 were associated with the changes of mean F_0 SD and mean SPL. The values of the correlations were not very strong, however, and the information yielded by the variables was thus not overly redundant. Second, some changes may have originated from the circumstances. Third, the voice changes may have arisen from a circadian rhythm, which is the basic nature of human physiology and emerges in metabolic events and muscle coordination.[43] Fourth, the changes could be a consequence of the work of the vocal apparatus, which first leads to vocal warm-up and after that to vocal fatigue.

Although some studies have been undertaken to analyze the fluctuations in the voices of speakers during the day, the effect of circadian rhythm has remained obscure. According to Nittrouer et al[44] and Garrett and Healey,[45] no statistically significant changes took place in F_0 or SPL during a day. Only F_0 SD was found to increase (1.3 Hz in females).[45] Hall,[46] in contrast, found F_0 to increase by an average of 2.3 Hz between the morning and the afternoon. Both of these values are smaller than the increase of the variables in the present study.

In addition to the contradictory results, conclusions about the within-day variation are also difficult to make due to the reason that no information has been given about speaking between the measurements in the studies. It can be inferred from the study of Hall that the participants talked between the measurements. In one study, speaking between the measurements was taken into account: the participants were not allowed to talk at all before the last measurement in the afternoon.[47] According to this study, none of the acoustic variables changed during the day. Since the participants of this study were men, correspondence with our results is not necessarily complete. On the basis of these previous findings, we assume that the within-day variation can explain a small part of the variable changes at the most.

On the basis of previous studies,[8,19,48] we expected vocal warm-up to take place after the beginning of talking (change between T1 and T2). Vocal warm-up has been found to raise F_0 and also SPL in soft phonation. Our data revealed no significant alterations in F_0, whereas SPL SD changed. However, it did not increase but rather decreased. This suggests that the demands of the classroom situation possibly prevented any vocal warm-up. In addition, the psychophysiological state of the teacher at the beginning of the lesson may differ at the middle of the lesson. At the beginning of the lesson, there are elements that may increase the teacher's arousal and stress level, such as the use of attention maneuvers or disciplinary utterances. The elevation of these levels has been shown to raise SPL.[47,49,50,51] The values of SPL SD have obviously decreased for the same reason.

The rise of F_0 can be assumed to be caused by voice usage that is due to voice loading. This finding agrees with much of the past research.[3,8,20,26,27] Also, the magnitude of the F_0 rise is consistent with the changes (6–19 Hz) reported in these investigations. Some other investigation, however, have provided contrary evidence (no change[5,21] or decreasing tendency[29]).

Two explanations for the F_0 rise have been offered in the literature. In the study of Stemple et al,[3] the F_0

of 10 participants increased after a two-hour period of voice loading. According to the researchers, this was a consequence of weakness of the thyroarytenoid muscle. When the muscular layer of the thyroarytenoid muscle slackens, the cover and transition layers of the vocal folds stiffen. This leads to an increase of the rate of vibrations in the vocal folds and hence a rise of the F_0.

Vilkman et al[8,19] have suggested another explanation. Forty males and 40 females participated in their study, the setting of which simulated teachers' working day (5×45 min). The results demonstrated changes in several parameters of voice, one of which was an increased F_0. The interpretation proposed by the authors for the phenomenon was that the changes were caused by the speakers' compensatory reactions to alterations in their voice. When compensating for the physiological changes, which could be alterations in the mucosa, the speaker increases the frequency of vocal fold vibration and the glottal adductory forces (hyperfunction). This increased constriction influences the F_0 indirectly. It increases the subglottal pressure, which adds tension to the vocal folds and, consequently, raises the F_0.[16]

Because we have no direct way of investigating the changes due to loading in the metabolic or functional state of the vocal folds yet, the question about the physiological reason for loading changes remains unanswered. Nevertheless, some observations seem to support the compensatory explanation rather than the hypothesis of muscle weakness for the results obtained in the present study. A finding computed from the voice samples of the same teachers as in this study indicated that the participants were capable of producing a low voice pitch even after the last lesson of the working day.[24] Furthermore, the bigger F_0 rise of the FC group than that of the MC group (present study) due to loading does not support the view of true muscular fatigue.

Effect of voice complaints on voice changes

According to the results, the levels of the variables in the FC and MC groups did not significantly differ from each other. However, a tendency was found for the levels of all the measured variables to be mostly higher among the teachers with more voice complaints than among the teachers with fewer complaints. This means that the teachers with more voice problems tend to use higher and louder voice, to vary it more, and also to talk somewhat longer than the teachers with a healthier voice. The differences did not exceed the level of statistical significance due to the large interindividual variation and the small group size—a well-known problem in voice studies.

Some differences between the subgroups were found, however. Unexpectedly, F_0 rose significantly only in the teachers with fewer voice complaints. Kostyk and Rochet[10] also found in their study that their participants' voices altered in different ways depending on the severity of voice complaints. The researchers interpreted this to indicate that the participants employed different strategies to cope with voice loading.

Another explanation for the different changes could be that the rise in the values of the variables is, in fact, a normal physiological phenomenon due to loading, and that this trend is more apparent in speakers whose voices are in a good condition. The tendency toward more distinct changes in the participants with fewer voice complaints was also seen in our previous study on spectral changes during a working day.[25] Thus, a change in physiological functions may illustrate healthy and normal adaptation to a situation,[11] while a lack of change may imply that some disorder has prevented the vocal organ from working in a normal way. Indeed, this phenomenon has also been observed in other human organs: heart studies have shown that, in exercise tests, systolic blood pressure increases in healthy persons, but does not change or may even decrease in patients with coronary heart disease.[43]

In addition, the MC and FC groups differed in how the F_0 SD and the F_0 time changed. The F_0 SD enlarged and the F_0 time decreased for the MC group. To date, little attention has focused on the relationship of F_0 SD to voice loading. There is, nevertheless, some evidence to suggest that enlarged F_0 SD can be a sign of strained voice, although the correspondence is not satisfactory. The relationship between voice disorders and F_0 SD was detected by Hammarberg,[33] who analyzed *reading* samples and found that larger than normal F_0 SD accompanies a hyperfunctional, rough or unstable voice. Thus, enlarged F_0 SD may indicate an instability of laryngeal function, and one possible reason for this could be impaired coordination of movements, which is a symptom of fatigue.[13]

The power of F_0 SD to manifest voice loading changes calls for further investigation.

The finding that the MC teachers reduced their F_0 time in the last lesson may have resulted from their need to conserve their voice apparatus due to their feelings of fatigue. In contrast, the FC teachers were able to increase the talking time for the same time period. The fourth difference between the subgroups, the decrease of SPL SD for the teachers with fewer complaints, probably arose from the same reason as the alteration for the whole group, the issue that was discussed early in the Discussion section.

Some methodological considerations

The nature of the present study was explorative rather than confirmative: the purpose was to open up new perspectives toward the phenomenon of voice loading and fatigue. For this reason the selected study setting was the combination of qualitative and quantitative methods. We tried to search such features from the qualitatively collected data to which statistical analysis could be applied. This unconventional decision caused many of our results to be complex and difficult to interpret.

One problem of the present study concerns the validity of the allocation of participants into subgroups. Some individuals are neither sensitive to symptoms of vocal fatigue nor familiar with describing them. Because of this, both of the subgroups are likely to include participants who do not actually belong there. Thus, the setting of the present study would have needed more participants in each subgroup. Another possibility could have been to have more homogeneous subgroups. For instance, one group might have consisted of speakers who have no or only minimal voice difficulties and the other of speakers who experience problems almost every week.

In order to better understand the influence of classroom circumstances, future work should examine voice data in a qualitative way. The vocal activities of teachers and pupils could be studied during lessons and a relationship between the teaching situation and voice usage needs to be analyzed. From the point of view of clinical practice, it would be beneficial to find any potentially harmful vocal habits used by teachers. In our data, possible vocal misuse was observed in the teachers of 7- and 8-year-old children. When teachers began to speak, their voice pitches rose very fast and were sometimes as high as 650 Hz. Voice usage of this kind probably arises from nursery speech.[52]

The main difficulty in voice loading studies, however, may be the problem of measuring small loading effects. When investigating shoulder muscles, Öberg Sandsjo, and Kadefors,[53] found that loading changes could be measured after a high load, but not after a prolonged low load, despite significant subjective complaints. Indeed, this seems to be true of voice loading studies, too. The problem calls for more attention.

SUMMARY

The most distinct result of this study was the F_0 rise during the working day, and this change emerged especially for the FC group. This finding may indicate that the F_0 rise is a consequence of the normal physiological adaptation of the vocal apparatus to loading and, hence, a sign of healthy voice. The voice changes found in the MC group were the enlarged F_0 SD and the decrease in the F_0 time. These changes—together with the teachers' predisposition to voice problems and a tendency to use a louder and higher pitched voice—may suggest that the MC group's voices became fatigued during teaching. The vocal apparatus of these teachers did not have enough capacity to react to loading in the same way as the laryngeal system of the teachers with healthier voices was able to.

Thus, our results support the opinion, which the disciplines of occupational ergonomics and exercise physiology have given about the phenomenon "fatigue due to loading." Voice fatigue also seems to be a continuum with a wide range of adaptations,[11,13] which begin at the onset of the activity, and at first, they can be seen as an increase in physiological preparedness. During the early stages of fatigue, the compensatory mechanism is probably acting and, consequently, the effort increases. When the loading continues and the fatigue increases, symptoms of muscular fatigue begin to emerge.

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APPENDIX A

Voice Questionnaire for Teachers

Please read the statements presented below and circle one number to correspond with each statement, indicating how frequently you experience the situation described.

Alternatives
1 = Less seldom than once a year or never
2 = A couple of times a year or occasionally
3 = About once a month or quite often
4 = Almost every week or very often

1. My voice gets tired after a long period of talking.
   1 2 3 4

2. My voice is hoarse without infection.
   1 2 3 4

3. I feel a lump and/or mucus in the throat.
   1 2 3 4

4. When I talk a lot, my throat hurts.
   1 2 3 4

5. My voice does not have good quality in situations where much talking is needed.
   1 2 3 4

6. My voice does not penetrate noise.
   1 2 3 4

7. I have voice breaks when talking.
   1 2 3 4

8. I have had aphonia without infection.
   1 2 3 4

9. I have had sick leaves due to voice problems.
   1 2 3 4

APPENDIX B

Scoring

The answers to the questionnaire are scored to determine the participant's propensity to voice fatigue problems. Because statements 2, 8, and 9 were considered to illustrate more serious voice problems, higher scores were assigned to them.

Statements 1 and 3–7.	*Statements 2, 8, and 9*
Alternative 1 = no	Alternative 1 = no
Alternative 2 = 2	Alternative 2 = 3
Alternative 3 = 4	Alternative 3 = 5
Alternative 4 = 7	Alternative 4 = 8