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RESEARCH ARTICLE

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Self-reported voice disorders of teachers and indoor air quality in schools: a cross-sectional study in Finland

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ABSTRACT

Objective: We aimed to study the association between self-reported voice disorders among teachers and indoor air quality in school buildings.

Methods: We performed a questionnaire study of 538 Finnish teachers working in 67 school buildings utilizing both perceived and technical evaluations; the agreement between these two assessments was also studied. The technical assessment was provided by technical experts.

Results: Teachers with voice disorders reported significantly more complaints from indoor air than those without voice disorders. The results also indicated a possible connection between the technical assessment and voice disorders. After adjustment for sex, stress and asthma, the prevalence of voice disorders was 47% higher in teachers working in renovated buildings compared to those working in the non-problem buildings (aRR1.47; CI 95% 1.11–1.95). The prevalence of voice disorders was 28% higher among teachers working in buildings with problems compared to those working in non-problem buildings (aRR 1.28; 95% CI 0.99–1.64).

Discussion: In our study, poor perceived indoor air was significantly associated with self-reported voice disorders in teachers and there was an agreement between the perceived and technical assessments. Our results also indicated a possible connection between the technical assessment and voice disorders. Our results imply the need for longitudinal research with technical assessment to study the effect of renovation on voice disorders.

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Voice disorder; teacher; school building; work environment; indoor air; technical assessment; perceived; complaints

Introduction

Respiratory symptoms are associated with indoor air problems but the evidence of voice symptoms is scarce [1,2]. However, the voice is an essential tool in teaching and a well-functioning voice is important in this profession. In addition, voice problems are argued to be two-to-three-fold more common in teachers than in the general population and the trend is increasing [3,4]. According to new findings, the prevalence of voice disorders is 54% for Finnish teachers [5]. In studies concerning moisture damage and health, voice symptoms are mentioned relatively seldom and usually treated as a respiratory symptom, defined as hoarseness [6]; however, in the context of this study, hoarseness will be considered as one of the voice symptoms. In one intervention study [7], hoarseness was significantly more common for teachers in the two moisture-damaged school buildings than in the non-damaged, before renovation.

In a speech profession, it is obvious that the vocal load and individual factors play a key role in voice disorders. In addition, the work environment is a significant variable associating with voice symptoms in teachers [8,9]. The results in a twin study [10] indicate that the etiology of vocal symptoms may be more environmental in a voice-demanding occupation. A component of the indoor environment is indoor air. Poor indoor air quality (IAQ) refers objectively to contaminants in the air and inadequate ventilation [11,12] whereas subjectively it is often perceived as stuffy air, dry air, insufficient ventilation, and dust or dirt, as reported by the staff in Finnish schools [13]. As noted, interactions between the factors exist in addition to large individual differences, presenting challenges to an evaluation [8,12,14,15]. Poor IAQ together with extensive voice use is a hazardous combination that has an influence on the voice; e.g. the vibratory properties of the vocal folds or the fundamental frequency [8]. Studies related to low humidity and voice problems indicate hyper functional changes in the voice [16]. Inadequate ventilation and dryness are found to associate with voice symptoms and exposure to dust may lead to a hoarse and weak voice [17]; dust is also frequently associated with irritation and may contain pollutants [14]. Dry air, which may also indicate air pollutants, deteriorates

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Supplemental data for this article can be accessed here.

the mucous layer in the airways and the viscoelastic properties of the vocal fold mucosa [15,16]. Dry air is also found to increase the phonation threshold pressure [16] and decrease mucosal wave amplitude and frequency in *in vitro* experiments [18]. As noted [9], the indoor environmental factors were often self-reported and the definitions of voice symptoms remained mostly inconsistent.

There is little research on the relationship between voice disorders and IAQ. Therefore, specific studies with both external and perceived assessments of IAQ are needed [9]. The present study is a subsample of an initial epidemiological study of 1 198 teachers performed in three cities across Finland designed to address voice disorders, work ability, and the indoor environment in school buildings. The first results [5] focused on individual factors associated with voice disorders. We concluded that stress is the most significant explanatory variable with a 3.6-fold risk as regards voice disorders. With the aim of exploring the relationship of voice disorders in teachers and IAQ, we focused on the associations between (1) self-reported voice disorders and perceived IAQ, (2) self-reported voice disorders and technical assessment, and (3) perceived and technical assessment. Based on the previous findings [7,8], we hypothesized that poor perceived IAQ and a technically assessed poor condition of the school buildings would be associated with voice disorders. In addition, we expected that there would be an agreement between these two assessments [1].

Materials and methods

We collected the data [19] on self-reported voice disorders and perceived IAQ by means of a questionnaire (See Supplemental file from questionnaires used for the study.) in March 2017. For the present study, we selected the participants who worked in primary and secondary schools in a city in southern Finland because a technical assessment was available for every school building. The response rate of the sample was 38%, which was expected in the calculation (35–40%). There were 538 teachers working in 39 of the 40 schools in the city. The schools consisted of altogether 67 buildings. The participants only included full-time teachers in Finnish speaking schools and excluded the respondents who were working in two or more buildings or whose specific working building was not identified. The technical assessment was provided by two technical experts. The study flow chart is illustrated in Figure 1.

The Ethics Committee of the University of Turku gave the ethics approval (Statement 26/2016). A request for permission to conduct the study was also sent to and endorsed by the Education Department of the city in which it was performed. We sent the questionnaire directly to the work email address of the participants and they were able to answer the questionnaire voluntarily and anonymously. The participants gave a written informed consent at the inclusion of the material pertaining to themselves; they acknowledged that they cannot be identified *via* the paper and that they understood they had been fully anonymized by the researchers. The principals were asked to inform and encourage their teachers to participate in the study.

Questionnaire on voice disorders

To assess voice disorders in Finnish teachers, we utilized a concise questionnaire to motivate the teachers to participate. The screening questionnaire consisted of questions about the occurrence of seven different vocal symptoms. The seven symptoms were *morning hoarseness*, *voice becomes strained or tired*, *voice becomes low or hoarse*, *voice breaks*, *difficulty in being heard*, *throat clearing or coughing*, and *pain around larynx*; for analysis purposes, we defined *hoarseness* from the symptoms *morning hoarseness* and *voice becomes low or hoarse*. The response alternatives were *every day*, *every week*, *less often*, and *never*. A voice disorder was defined as having two or more voice symptoms occurring weekly or more often in the previous 12 months. This definition was also supported by a laryngological evaluation once the screening questionnaire was developed [20,21]. Different combinations of these vocal symptoms have previously been used in several questionnaire studies [4,5,20–23].

Backgrounds variables

We assessed *sex*, *age*, *the number of years a teacher had been working in the present building*, *profession* (class teacher, subject teacher, special education teacher), and *subjects taught*, grouped into four groups (*languages* including also mother tongue and literature; *mathematical subjects* including mathematics, physics, chemistry; *theoretical subjects* including health education, religion and ethics, history and social studies, biology, geography; *practical subjects* including physical education, home economics, visual arts, music, crafts). *Asthma* was assessed with the question "Has your doctor stated that you have asthma?"; we also asked whether *asthma medication* was used. *Smoking* was handled as a categorical variable ("never smoked" or "ex-smoker"–"current smoker"). In addition, we measured *stress at work* with a validated question using a 5-point Likert scale [24]. For analysis, we dealt withthe stress variable as two categories; subjects with "little," "not at all," or "somewhat" were assigned as not having stress and those with "very much" or "rather" were assigned as having stress.

Assessments of IAQ

We utilized two variables, both focusing on ventilation, humidity, and impurities [12]. (1) The perceived IAQ assessment was based on the MM 040 questionnaire [25]. The questionnaire has been validated by school staff [13] and was also developed for office workers [26], hospital staff [27], and school pupils [28], all of them with a different combination of questions. In our study, we asked about complaints concerning *stuffy* "bad" *air, dry air, insufficient ventilation, smell of mold or an earthen cellar, other unpleasant odors, dust or dirt* in the work environment over the last three months. These complaints are closely linked to indoor air circumstances in schools and voice symptoms [8,11,12,14]; the other indoor environment complaints were

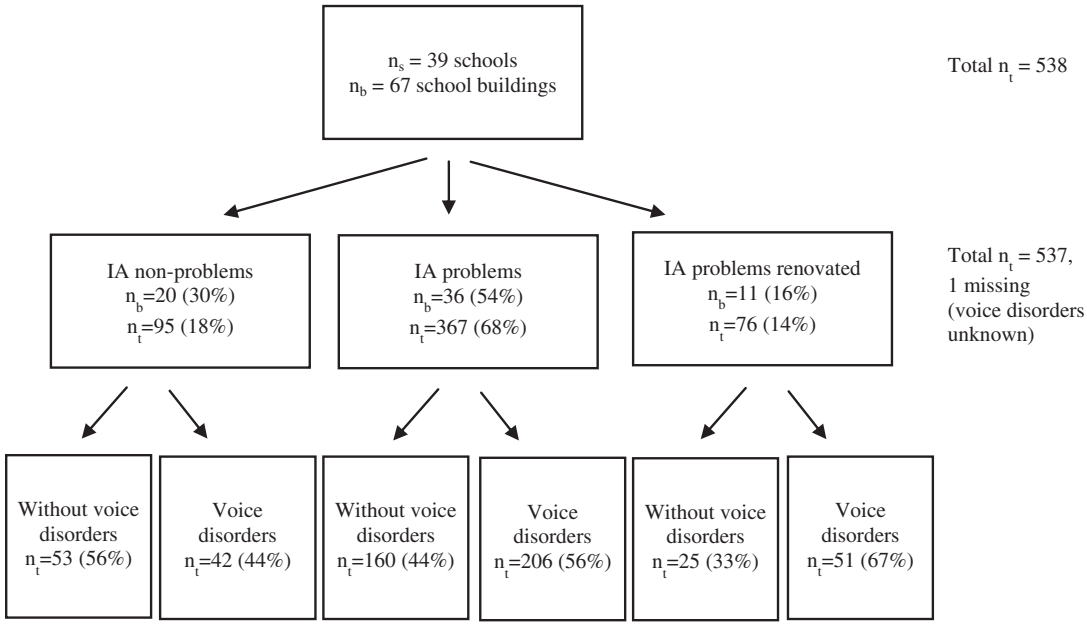

Figure 1. Study flow chart. (n_t: number of teachers; n_s: number of schools; n_b: number of school buildings; IA: indoor air).

assessed in our previous study [29]. The alternatives for the factors were *weekly*, *sometimes*, and *no, never*. In the analysis, the complaints were dealt with as two categories (*weekly–never*), while *sometimes* and *no, never* were combined as one category.

(2) The technical assessment was performed by two technical experts from the City's Real Estate Center who had actively worked with the buildings of interest. They were not aware of the results of the perceived IAQ. The two experts were interviewed at the same time by the researcher because of limited resources. The data thus obtained provided an overall evaluation of the deficiencies in the school buildings that are likely to decrease IAQ in school buildings and are closely linked to voice problems: challenges with ventilation and impurities. The thermal conditions were not included, as the technical assessment focused on the condition of the school buildings. The information was based on the recollection of the experts concerning the investigations and measurements that had been carried out in the school buildings during previous years from e.g. ventilation, air contaminants, and moisture damage. The experts classified the condition of the school buildings into four categories: (1) *IA non-problems*, (2) *IA problems, not renovated*, (3) *IA problems, partially renovated*, (4) *IA problems renovated*. For analysis purposes, the variable was dealt with using three categories, thus *IA problems, not renovated* and *IA problems, partially renovated* were combined as one category; this classification is used in the Finnish benchmarking data of the National Institute for Health and Welfare (THL) to evaluate health promotion activities in schools [30]. The resulting variable is referred to as the *technical assessment*.

The classification was based on the consensus of the two experts. The overall agreement of the experts was 79% (n_b=53) and these results were also verified using documentation. In the case of a disagreement between the experts (n_b=14), we used additional data to make the final decision following the order of precedence; (a) *additional information on buildings given by the experts* available from 35 buildings and related to e.g. renovations or complaints, (b) *inspection reports from the City's Environment Center were* available for 41 buildings for three years prior to the survey with the options *No comments–Renovation work recommended–Health impacts*, and (c) *targeted benchmarking data from THL* available from 22 schools for two years prior to the survey with the options *No deficiencies–Deficiencies–Renovated*. The classification is described in detail in the Supplemental file from a dataset on the school buildings.

The school buildings were constructed between 1904 and 2016 and 32 of the buildings had been thoroughly renovated at least once. According to the experts, there were centralized mechanical supply and exhaust systems in most of the buildings, and, as is usual in Finland, these were mainly switched off during the night and at weekends, except in newly renovated buildings and buildings with mold and moisture damage. There were between 1 and 23 teachers working in each building (mean 8), and the number of pupils, which also indicated the size of the school, was between 25 and 1000 per building (n_b=54; mean 289). We did not assess the number of pupils per class because the teachers tended to have several groups of different sizes each day, depending e.g. on the subject and the need for learning support. Thus, even an average group size would be an inaccurate reflection of the working condition of the teachers. What should be mentioned is that there was only limited information available on the buildings and the amount of missing data was relatively high.

Statistical analysis

When evaluating the association between one background variable and voice disorders separately, we performed a Chi-

square test or a Fisher's exact test. A log-binomial regression model [31] was used to study associations between voice disorders and technical assessment, sex, stress, or asthma. In addition, unadjusted (uRR) and adjusted relative risk (aRR) for these factors together with a 95% confidence interval (CI) were calculated. Adjustments were made for sex, stress, and asthma. In the unadjusted model, only technical assessment was included.

All statistical tests were performed as 2-tailed, with a significance level set at 0.05. Fischer's Exact Test was used to assess the results of the buildings with less than five occupants. The analyses were performed using JMP 14 Pro for MacOS and SAS® System, version 9.4 for Windows (SAS Institute Inc., Cary, NC, USA).

Results

Description of the prevalence of voice disorders

The prevalence of self-reported voice disorders was 56% (CI 95% 51–60), assessed over a 12-month period. The most common voice symptoms were *voice becomes strained or tired* and *hoarseness*, both of which were reported by more than half of the participants; eighty-five percent of which were female. The females suffered more from voice disorders than the males (Table 1). The mean *age* was similar between those subjects with and without voice disorders. *Stress* was reported by 27% of the subjects and those with stress had significantly more voice disorders than those without stress. There was a 14% prevalence of *asthma* among the teachers and 11% used an asthma medication. Both *asthma* and *asthma medication* were significantly associated with voice disorders. Four percent were current smokers. Voice disorders were not associated with the teachers' *profession* or *subject groups*.

IAQ per school buildings

According to the results of the perceived IAQ, 11–51% of the subjects reported IAQ complaints; *stuffy* "bad" *air, insufficient ventilation,* and *dust or dirt* were reported mostly (48–51%) (Figure 2). Females reported significantly more additional complaints than just the *smell of mold or an earthen cellar*. *Age* was not associated with perceived IAQ with the exception that those who reported *stuffy* "bad" *air* were slightly younger on average (41.4 vs. 43.2 years). *Asthma* was not associated with perceived IAQ; *asthma medication* associated significantly only with *dry air* (p=.043).

With regards to the *technical assessment*, 30% (n_b=20) of the school buildings were without IA problems. *IA problems* occurred in 54% (n_b=36) of the buildings, and 16% (n_b=11) of the buildings had been *renovated because of IA problems*. Thirty-five percent of the buildings were constructed before 1970, 35% between 1970 and 1989, and 30% were constructed in 1990 or later. The year of construction was significantly associated with *IA problems*; the older the building, the more *IA problems* (p<.0001). Renovations where mostly carried out in the buildings constructed between 1970 and 1989. The occurrence of *IA problems* was

Table 1. Associations between voice disorders and the background variables.

	Total, n_t (n_t=538)	Without voice disorders, n_t (n_t=238)	With voice disorders, n_t (n_t=299)	p-Value[a]
Sex				
Male	80 (15)	44 (55)	36 (45)	0.034
Female	443 (82)	189 (42)	258 (58)	
Missing	15 (3)			
Age	532 (99)	43 (25–64)	42 (25–65)	0.37
Missing	6 (1)			
Years in building	532 (99)	7 (1–31)	7 (1–37)	0.64
Missing	6 (1)			
Profession				
Class teachers	234 (43)	102 (44)	132 (56)	0.54
Subject teachers	197 (37)	84 (43)	113 (57)	
Special education teachers	106 (20)	52 (49)	54 (51)	
Missing	1 (<1)			
Smoking				
Never smoked or ex-smoker	512 (95)	230 (45)	282 (55)	0.17
Current smoking	23 (4)	7 (30)	16 (70)	
Missing	3 (1)			
Asthma				
No	437 (81)	205 (47)	232 (53)	0.0054
Yes	69 (13)	20 (29)	49 (71)	
Missing	32 (6)			
Asthma medication				
No	478 (89)	223 (47)	255 (53)	0.0021
Yes	59 (11)	15 (25)	44 (75)	
Missing	1 (0)			
Stress				
No	389 (72)	188 (48)	201 (52)	0.0018
Yes	147 (27)	49 (33)	98 (67)	
Missing	2 (<1)			

n_t: number of teachers; mean with range (min-max) are presented for continuous variables and counts with percentage for categorical variables.
[a]Chi-square test and logistic regression.

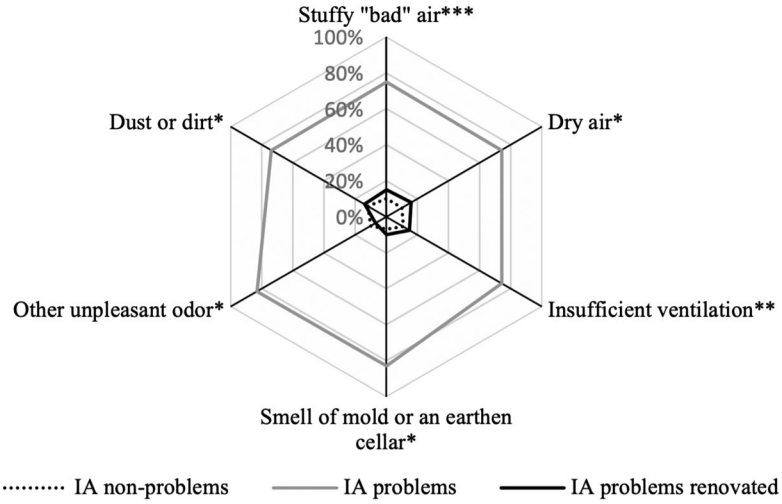

Figure 2. Indoor air complaints compared to technical assessment (n_t=538). Significant associations between voice disorders and each complaint are indicated as ***p<.001; **p<.01; *p<.05 (n_t: number of teachers).

significantly associated with the *number of pupils per building*. The buildings with fewer than 200 pupils had the least *IA problems*. *Sex*, *age*, *asthma*, *asthma medication*, *profession*, or *subject groups* did not associate with the *technical assessment*. As regards the IAQ complaints, the special education teachers clearly reported less *dust or dirt* compared to the other teachers (36% vs. 52%–54%; p=.0062). In addition, the teachers of mathematical subjects as well as artistic and practical subjects reported significantly more *dust and dirt* compared to teachers of languages or theoretical subjects (60–69% vs. 40–42%; p = .0087).

Relation between voice disorders and IAQ

As Table 2 shows, voice disorders were significantly associated with all IAQ complaints (p-values <.0001). The association between voice disorders and the *technical assessment* was significant (p=.010). Voice disorders were more prevalent among teachers employed in buildings with *IA problems* (56%), than those in buildings without problems (44%), but less often than in the buildings where the problems had been corrected (67%). Furthermore, voice disorders were more prevalent in the buildings that were constructed in 1970 or later than in the older buildings. Voice disorders were not associated with the *number of pupils per building*. To study the association between voice disorders and the *technical assessment* more deeply, we created a model including background variables (*sex*, *stress*, *asthma*) (Table 3). After adjustment for *sex*, *stress* and *asthma*, the prevalence of voice disorders was 47% higher in teachers working in renovated buildings compared to those working in the buildings without IA problems (aRR1.47; CI 95% 1.11–1.95). The prevalence of voice disorders was 28% higher among teachers working in buildings with *IA problems* compared to those working in buildings without problems (aRR = 1.28; 95% CI 0.99–1.64). The inclusion of the covariates had no significant effect on the unadjusted relative risk (uRR). When studying the association between voice disorders and each complaint of PIAQ with the same model, all complaints were significantly associated with voice disorders.

The technical assessment was significantly associated with all complaints of IAQ. The occupants in the buildings without IA problems made fewer IAQ complaints than those in the problem buildings or in the renovated buildings.

Discussion

According to our results, teachers with self-reported voice disorders reported significantly more IAQ complaints than those without voice disorders. The results also indicated a possible connection between the technical assessment and voice disorders. There was an agreement between the perceived and technical assessments.

Relation between voice disorders and IAQ

In our study, teachers with voice disorders reported more IAQ complaints than those without voice disorders. The results agree with previous findings from self-reported data. One cross-sectional study [32] found that insufficient ventilation in classrooms was significantly associated with dysphonia in 2 103 elementary education teachers in a random sample of 83 schools. Likewise, hoarseness was related to stuffy or polluted air for 846 university teachers [33]. In a questionnaire study of 1878 teachers [34], voice complaints were significantly associated with humidity and irritants in the classroom; the authors wish to pointed out, however, that psycho-emotional factors, such as stress, may be a more serious risk factor for the voice than the environment. Our results also agree with multiple other studies [9,23,35]. Contrary to our findings, results of a case-control study of

Table 2. Associations between voice disorders and the characteristics of the school buildings.

		Total, n_t (%) (n_t=537)	Without voice disorders, n_t (%) (n_t=238)	With voice disorders, n_t (%) (n_t=299)	p-Value[a]
Perceived IAQ					
Stuffy "bad" air	No	260 (48)	163 (63)	97 (37)	<.0001
	Yes	273 (51)	72 (26)	201 (74)	
Missing		5 (1)			
Dry air	No	337 (63)	193 (57)	144 (43)	<.0001
	Yes	190 (35)	41 (22)	149 (78)	
Missing		11 (2)			
Insufficient ventilation	No	273 (51)	168 (62)	105 (38)	<.0001
	Yes	257 (48)	68 (26)	189 (74)	
Missing		8 (1)			
Smell of mold or an earthen cellar	No	467 (87)	223 (48)	244 (52)	<.0001
	Yes	58 (11)	11 (19)	47 (81)	
Missing		13 (2)			
Other unpleasant odors	No	417 (77)	210 (50)	207 (50)	<.0001
	Yes	107 (20)	21 (20)	86 (80)	
Missing		14 (3)			
Dust or dirt	No	268 (50)	148 (55)	120 (45)	<.0001
	Yes	262 (49)	85 (32)	177 (68)	
Missing		8 (1)			
Technical assessment					
IA non-problems		95 (18)	53 (56)	42 (44)	.010
IA problems		366 (68)	160 (44)	206 (56)	
IA problems renovated		76 (14)	25 (33)	51 (67)	
Missing		1 (<1)			
Constructed					
Before 1970		182 (34)	94 (52)	88 (48)	.030
From 1970 to 1989		228 (42)	88 (39)	140 (61)	
1990 or later		119 (22)	52 (44)	67 (56)	
Missing		9 (2)			
Number of pupils per building					
Less than 200		35 (6)	20 (57)	15 (43)	.28
From 200 to 500		268 (50)	115 (43)	153 (57)	
More than 500		176 (33)	78 (44)	98 (56)	
Missing		59 (11)			

IAQ: indoor air quality; n_t: number of teachers.
[a]Chi-square test.

425 female teachers [36] showed that complaints of humidity, dust, and chemical substances did not correlate with clinical signs of voice disorders.

The results indicated a possible connection between the technical assessment and voice disorders. Our data showed that voice disorders may be more prevalent in the buildings with technically assessed IA problems than in the buildings without such problems; the p-value was .059, showing a trend towards a significant association. The p-value showed a significant association between voice disorders and the technical assessment as a whole (.010) whereas the confidence intervals of aRR demonstrated only a nearly significant association between non-problem and problem buildings (CI95% 0.99–1.64). Compared to other studies with an external evaluation, the results vary. One study [23] found a significant association between voice symptoms and poor IAQ. The study was performed in 39 classrooms utilizing the same voice questionnaire that was used in our study and a voice ergonomic checklist [37] involving IAQ factors. Contrary to this, another study [38] found no differences in humidity or CO_2 level in the classrooms of 14 teachers with voice problems compared to 14 of their vocally healthy colleagues. Importantly, they suggested that the feeling of dryness might be a sign of breathing through the mouth because of e.g. a blocked nose; breathing through the nose is essential for moisturizing inhaled air.

Our findings show that voice disorders were the most evident in the buildings where the problems had been corrected. The result is surprising in the light of our hypotheses. We expected that the technically assessed poor condition of the school buildings would be associated with voice disorders. Thus, the corrections should improve the symptoms rather than worsen them [2]. A possible explanation is that all the renovations may not have been conducted properly even though in the classification, the category *IA problems renovated* included only buildings with completed renovations, not partial renovations. After the renovations, the enhanced ventilation may decrease indoor air humidity and the voice symptoms may thus be prolonged and new symptoms appear. Being that stress is found to be a clear factor for voice disorders [5,22], it may be a partial explanation of the long-term voice problems if the process of improving indoor air has been protracted and contradictory. In cases where the renovation is because of moisture damage, previous findings [39] have indicated the possibility of a very slow healing process in the mucosa of the upper airways after a long exposure to building dampness. Other results also suggest that the prevalence of hoarseness remained significantly higher in the moisture-damaged school buildings than in the non-damaged building in a three-year follow-up after renovation, while the prevalence of most of the other respiratory symptoms

Table 3. Unadjusted and adjusted relative risk between voice disorders and technically assessed indoor air quality.

Technical assessment	uRR (CI 95%)	*p*-Value	aRR (CI 95%)	*p*-Value[a]
IA problems vs. IA non-problems	1.27 (1.00–1.62)	0.052	1.28 (0.99–1.64)	.059
IA problems renovated vs. IA non-problems	1.52 (1.15–2.00)	0.0030	1.47 (1.11–1.95)	.0071
IA problems vs. IA problems renovated	0.84 (0.70–1.00)	0.058	0.87 (0.72–1.04)	.13
Sex		–	1.24 (0.97–1.60)	.092
Asthma		–	1.31 (1.08–1.59)	.0070
Stress		–	1.27 (1.08–1.48)	.0033

uRR: unadjusted relative risk; aRR: adjusted relative risk; CI: confidence intervals.
[a]Log-binomial regression model.

decreased [7]. There are also other possible explanations for the prolonged voice disorders. Problems with the voice, such as hyper functional changes, may relate to low humidity—especially in the winter period—, dust, or other deficiencies as well as their interactions in indoor air [8,16,17]. The changes in the vocal fold mucosa and the extensive vocal load in teaching work may offer one explanation for our findings [15,16,18]. However, this remains open to speculation. Considering that poor IAQ together with extensive voice use may have an impact on vocal apparatus [8], these findings may imply a potential hazard for teachers' ability to work.

IAQ per school buildings

Our results show that there were IA problems in more than half of the school buildings. In comparison with the previous studies concerning mold and moisture problems, the findings agree with a recent study of 27 Finnish hospital buildings where abnormal indoor air exposure was studied using a technical investigation and categorized in four classes by the probability of exposure [40]. The data showed that there were extensive microbial or moisture damage in 52% of the 95 building floors examined. However, our findings do not support the findings of the international school study (Health effects of indoor pollutants: Integrating microbial, toxicological and epidemiological approaches [1]) where the occurrence of moisture damage varied between 24 and 41%, assessed by trained staff. Likewise, the benchmarking data in previous years show that the occurrence of deficiencies has varied between 11 and 26% when assessed at the school—not the school building—level [30]. Our findings were inconsistent despite the fact that the school buildings were younger in our study than is the general case in Finland. Eighty-five percent of school buildings in Finland were built before 1990 whereas in our study, 72% of the buildings were constructed before 1990 [41]. As suggested, the old age of the buildings is one of the main problems causing poor IAQ [42]. However, voice disorders were most prevalent in the buildings constructed in the 1970s and 1980s. Overall, caution is needed when comparing studies with different study designs and definitions.

Relation between perceived and technical assessments

Our results showed that there was an agreement between perceived and technical assessments. The teachers reported significantly more IAQ complaints, i.e. *stuffy* "bad" *air, dry air, insufficient ventilation, smell of mold or an earthen cellar, other unpleasant odors,* and *dust or dirt*, in the school buildings with technically assessed IA problems than in the non-problem or renovated buildings. The findings are in line with earlier studies performed with an MM 040 questionnaire [27,42]. In Finnish hospital buildings, the employees reported more IAQ complaints in the premises that needed further investigations than in the premises with no need of renovation [27]. The most complaints were reported in the premises in need of immediate renovations. More specifically, the participants in another study were more likely to report mold odor in those parts of the buildings where moisture damage was verified [42]. One clinical study [43] also found significant associations between complaints of *stuffy* "bad" *air* and *dry air* and exposure factors such as relative humidity, measured in university buildings. In comparison, each complaint was more prevalent in our data than in the reference data from school employees (Figure 3) [13]. One reason for the differences might be that in the reference data schools that were not primary and secondary schools were included in the 122 schools used in the study. As stated in a survey of people in charge of the building stock of all the municipalities in Finland, the majority of indoor air problems are reported to exist in school buildings specifically used for primary and secondary education [41]. This is notable, because the consequences of poor IAQ are more far-reaching in a school environment than in e.g. an

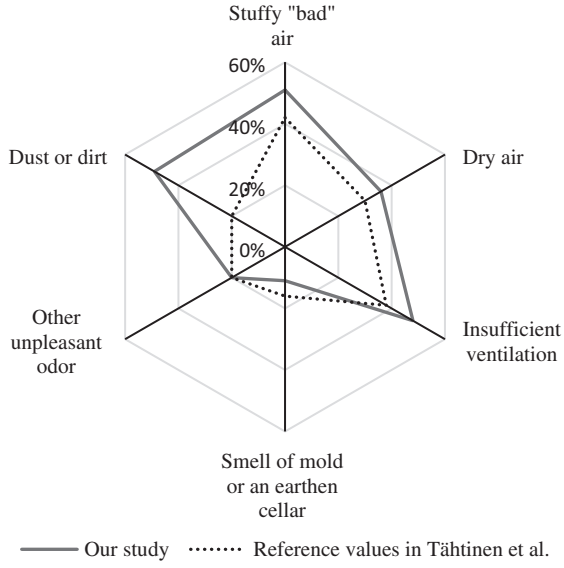

Figure 3. Perceived indoor air quality in our study (n_t=538) compared to reference values in Tähtinen et al. [13] (n = 5 241) [13]. (n_t: number of teachers).

office environment. Apart from the effect on the learning process of pupils, it may reduce the teachers' professional performance and even their ability to work [44]. Our findings related to the special education teachers reporting less *dust or dirt* than the other teachers may be due to the low number of pupils in special education classrooms. Inversely, experiments done in chemistry and physics classes as well as activities inartistic and practical subject classes may increase the amount of dust and dirt indicated in our results. It might also be noted, that it has been suggested that exposure to dust may lead to voice problems [17] and in our study, the special education teachers also reported less voice disorders than their colleagues, albeit insignificantly (51% vs. 56%–57%).

Voice disorders

Of the participants, 56% reported as having voice disorders. The prevalence is consistent with our initial study of 1 198 teachers across Finland (56%, CI 95% 51%–60% vs. 54%) [5]. Similarly, the results are in line with the earlier studies with large sample sizes where a lifetime prevalence of voice disorders was51% in a sample of 994 teachers at different school levels [45], and also 51% when voice disorders were defined as voice problems ($n = 504$) [46]. In addition, the prevelance in a 12-month period for 82 female teachers was 54% [47]. However, there are also contradictory findings [9], possibly due to the way in which the term "voice disorders" was defined. Using different definitions but the same recall period of 12 months, the prevalence of voice disorders varied with a wide range of between 15 and 80% [9].

In our study, female sex, stress, asthma, and asthma medication were potential confounding factors and they are also well-documented risk factors for voice disorders [5,48]. In addition, noise is generally accepted to be associated with voice disorders and also shown in our initial study of 1198 teachers [5]. Previous studies suggest that improving the ventilation rate which reduces the CO_2 concentration in classrooms may improve not only learning performance but also attendance in pupils [44,49] whereas IAQ factors such as low ventilation rate, moisture problems, or air pollutants can decrease attendance[50]. Teachers may use a louder voice when pupils are unsettled. The attendance may also be related to the occupant density. When there is a smaller group of pupils in a classroom, the ventilation can change the air more efficiently than when a room is densely populated [1]. In our study, the least IA problems occurred in the buildings with fewer than 200 pupils. However, caution is needed in when considering this comparison as the information concerning pupils was available only for 52% of the buildings.

Our analysis shows females reporting more voice disorders than males. However, the connection is not as obvious as in our initial study (p=.034 vs. p=.0004). The proportion of female teachers was similar to our initial study but slightly higher than in Finnish teachers in general (85%, CI 95% 81–87% vs. 79%) [51]. Although voice disorders are more prevalent in females than in males on the basis of physiological differences—such as the size of the larynx—the vocal load and environmental factors play a central role in voice disorders in teachers [10,52].

Strengths and limitations

The strength of our study was that we collected the data about voice disorders and the technical assessment independently. The evaluation of school buildings was performed with both technically assessed and perceived data whereas the self-reported data were mainly utilized to study voice symptoms [32–34]. To validate the questionnaire that asked the teachers to self-report IAQ, the experts assessed the condition of all 67 school buildings of interest. There were significant associations between perceived IAQ and the technical assessment, and the teachers reported more complaints in the buildings with IA problems than in the other buildings.

The strength of our study is also that the voice disorders were assessed with a clear definition of voice disorders and a limited recall period. In addition, the definition of voice disorders was supported by a laryngological evaluation once the screening questionnaire was developed [20,21]. The questionnaire is assessed as having a significant association with the Voice Handicap Index (VHI) [53] that is a validated questionnaire with 30 questions used worldwide; we used the screening questionnaire with a limited number of questions in order to motivate the teachers to participate. In studies focused on the health effects of poor IAQ, vocal symptoms are typically defined as hoarseness, however, this may also include vocal symptoms caused by infections or respiratory diseases such as asthma [7,54]. Our results are supported by a large sample that was representative in terms of professional categories. The percentage of class teachers was 43% (CI 95% 39–47%), compared to 44% among teachers in general in Finland [51]. Our findings are also supported by a very low amount of missing data from the questionnaires; as can be seen in Table 1, the participants answered almost every question.

The technical classification was supported by the Finnish benchmarking system but was performed more explicitly at the building level, not only the school level [30]. The experts were specialists in the field of maintenance and renovation work and had over 15 years' experience with the city. The experts were aware of the latest measurements and state of the buildings of interest. However, school buildings are large and there may be differences in how the experts evaluated the level of a deficiency and what they assessed as being an adequate renovation. There may also be deficiencies that are unknown in a building. As also noted, various interactions between the factors exist in addition to large individual differences, making the evaluation challenging [8,12,14]. Challenges have also been reported in international school studies [1]. In general, there are no unambiguous guidelines on whether a renovation has been done adequately as the interested parties—users, owners, occupational health staff—evaluate the buildings using different criteria e.g. whether the repairs are done correctly or whether a building is safe.

This can also be seen in the inspection reports of the City's Environment Center and the benchmarking data of THL. The inspection reports are based on a walk-through focusing on health impacts, and the reports may vary as regards how extensively and carefully the inspections are carried out. The benchmarking data is then based on a questionnaire from school principals who reported the results of the inspections every two years. The targeted benchmarking data from THL concerning mold and moisture damage was for a period two years prior to the survey; the data were collected from school principals and the data involved 22 schools, however, only 13 of them consisted of only one building which was the targeted information. The principals made a joint assessment involving all the buildings belonging to their school. What should also be mentioned is that the inspection reports and benchmarking data were from the three years prior to the study, and thus reflected the current situation. Accordingly, although we utilized an external evaluation of the school buildings, the classification is an assessment which may include a potential bias.

A potential source of bias is a tendency to over-report in questionnaire surveys. The low response rate of 38%—although in line with earlier voice questionnaires carried out with teachers [47,55],—may incur the risk that it is mainly those with voice problems who responded to the questionnaire and reported IAQ complaints. In addition to this, self-reported data may suffer from item interpretation [56]. A further limitation was that two voice symptoms were combined in the variables *voice becomes strained or tired*, *voice becomes low or hoarse*, and *throat clearing or coughing*. However, in order to achieve more accurate results, it is recommended that a doctor's diagnosis of voice disorders be used in future studies to provide more direct evidence of the existence of voice disorders.

In this study, we focused on the IAQ in school buildings. However, there are also other work environment factors and their interactions that may associate with voice disorders. Due to the fact that the study was carried out during March, when the school heating system was on, the temperature in the classrooms may have varied and this may have had an impact on voice symptoms, such as throat clearing; also, the coldest winter season was over, but the pollen season had not yet started. The association between voice disorders and indoor environmental quality is further discussed in our previous study [29].

Overall, supported by a large sample size, our results confirm the hypotheses that poor perceived IAQ is associated with self-reported voice disorders and there is an agreement between the technical assessment and the perceived IAQ. Voice disorders were the most evident in the buildings where the problems had been renovated. Voice disorders are also possibly more prevalent in the buildings with technically assessed IA problems than in the non-problem buildings. The voice is a vital component of effective teaching. Poor IAQ together with a continuing vocal load, imply that there is a need for protective actions as regards the risk groups of teachers in order to support their ability to work. In the cross-sectional study design, it is not possible to assess causality. More research is needed to assess the effect of renovations on voice symptoms as well as the interaction between voice disorders and IAQ on work performance in teachers.

In conclusion, poor perceived IAQ associated with self-reported voice disorders in teachers. The teachers with voice disorders made significantly more IAQ complaints compared to their colleagues. The results also indicated a possible connection between the technically assessed condition of the school buildings and voice disorders. There was an agreement between perceived and technical assessments. A continuous vocal load together with poor IAQ are potential hazards for the ability to work in teachers. Thus, teachers with such problems need special attention through occupational health care. Our results imply the need for longitudinal research to study the effects of renovations on voice symptoms.

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