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VOICE DISORDERS, STRESS, AND INDOOR ENVIRONMENTAL QUALITY:

A Cross-Sectional Study of Finnish Teachers

Hanna Vertanen-Greis

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The originality of this publication has been checked in accordance with the University of Turku quality assurance system using the Turnitin OriginalityCheck service.

Cover Image: Sara Vertanen and Ville Hakulinen

ISBN 978-951-29-8501-2 (PRINT)
ISBN 978-951-29-8502-9 (PDF)
ISSN 0355-9483 (Print)
ISSN 2343-3213 (Online)
Painosalama, Turku, Finland 2021

To My Loved Ones

UNIVERSITY OF TURKU
Faculty of Medicine
Department of Clinical Medicine
Occupational Health
HANNA VERTANEN-GREIS: Voice Disorders, Stress, and Indoor Environmental Quality: A Cross-Sectional Study of Finnish Teachers
Doctoral Dissertation, 149 pp.
Doctoral programme in Clinical Research
September 2021

ABSTRACT

Voice disorders are common in teachers. In addition to the extensive use of their voice, voice problems are associated with stress, a poor indoor environmental quality (IEQ), and frequently also with a decreased work ability. However, epidemiological data on these problems are scarce, and there is little information on the interaction between voice disorders, stress, and the IEQ concerning the work ability of teachers.

The overall purpose of this thesis was to study the variables associated with voice disorders, especially the stress at work, a poor IEQ, and the work ability of teachers. A cross-sectional study was conducted with 1 198 primary and secondary school teachers in three cities across Finland (81% females, 19% males). Voice disorders were assessed with a voice screening questionnaire. The stress at work and work ability were measured with validated, single-item questions. The indoor environment was assessed by using the MM 040 questionnaire, and a technical assessment of school buildings was utilized in relation to a subsample of 538 teachers.

The prevalence of voice disorders over the 12-month period was 54%, and stress was most significantly associated with voice disorders (OR 3.6). Teachers with voice disorders reported more indoor environmental complaints, such as *noise* and *stuffy air*, than those without voice disorders. The results also indicated a possible association between a poor condition of school buildings and voice disorders, and there was an agreement between perceived and technical assessments. Work ability was the best in the teachers without voice disorders or stress, and the prevalence of sick leaves was also the lowest in this group. Stress and voice disorders together had a stronger association with a decreased work ability than when they were evaluated separately. Voice disorders, stress, and the perceptions of a poor indoor environment, such as *stuffy air* and *dust*, were all clearly associated with work ability.

This study advances our understanding of teachers' work ability that particularly highlights the relation between voice disorders, stress at work, and a poor IEQ for their work ability. Follow-up studies are needed to investigate the causality of these three variables for work ability. In order to better maintain teachers' work ability, special attention should be paid to their occupational health, when there are problems rising from the IEQ, and the teachers suffer from voice disorders and stress at work.

KEYWORDS: Voice, voice symptoms, voice problems, stress at work, indoor air quality, perceived, technical assessment, work ability, absence due to sickness

TURUN YLIOPISTO
Lääketieteellinen tiedekunta
Kliininen laitos
Työterveyshuolto
HANNA VERTANEN-GREIS: Voice Disorders, Stress, and Indoor Environmental Quality: A Cross-Sectional Study of Finnish Teachers
Väitöskirja, 149 s.
Turun kliininen tohtoriohjelma
Syyskuu 2021

TIIVISTELMÄ

Äänihäiriöt ovat yleisiä opettajilla. Runsaan puhumisen lisäksi ääniongelmat liittyvät stressiin ja koulujen sisäympäristön puutteisiin. Niillä on yhteyttä myös alentuneeseen työkykyyn. Opettajien äänihäiriöiden, työhön liittyvän stressin ja sisäympäristön yhteisvaikutuksesta työkykyyn on kuitenkin vain vähän väestöpohjaista tietoa.

Tämän väitöstyön tavoitteena oli tutkia äänihäiriöiden yleisyyttä työhön liittyvään stressiin ja koulujen sisäympäristön puutteisiin sekä niiden yhteyttä opettajien työkykyyn. Kyselytutkimukseen vastasi yhteensä 1198 peruskoulun opettajaa kolmesta kaupungista eri puolilta Suomea. Äänihäiriöitä tutkittiin lyhyellä äänioirekyselyllä, ja muita muuttujia arvioitiin viisiportaisen stressikysymyksen, Työkykypistemäärän sekä MM 040 -sisäilmastokyselyn avulla. Osatutkimuksessa verrattiin koulujen sisäilman laatua opettajien äänihäiriöihin (n = 538) sekä teknisen arvion että itsearvioinnin avulla.

Noin puolella (54 %) tutkituista opettajista esiintyi äänihäiriöitä, ja stressi oli niiden merkittävin selittäjä. Äänihäiriöistä kärsivät raportoivat sisäympäristöön liittyviä puutteita, kuten *melu* ja *tunkkainen ilma*, selvästi muita enemmän. Koulujen teknisen arvion ja itsearvioinnin välillä oli merkitsevä yhteys, ja tulokset viittasivat siihen, että äänihäiriöillä olisi yhteyttä myös teknisesti arvioituun koulurakennusten huonoon kuntoon. Paras työkyky oli opettajilla, joilla ei ollut äänihäiriöitä tai stressiä, ja heillä oli myös vähiten sairauslomia. Stressi ja äänihäiriöt olivat vahvemmin yhteydessä heikentyneeseen työkykyyn yhdessä kuin erikseen arvioituina. Äänihäiriöt, työhän liittyvä stressi ja sisäympäristön puutteet, mm. *tunkkainen ilma* ja *pöly*, olivat kaikki selkeästi yhteydessä alentuneeseen työkykyyn.

Tämä tutkimus tuo lisää tietoa opettajien työkyvystä ja korostaa erityisesti äänihäiriöiden, työhön liittyvän stressin ja koulujen sisäympäristön puutteiden yhteyttä alentuneeseen työkykyyn. Seurantatutkimukset ovat tarpeen syy-yhteyden selvittämiseksi. Opettajien työkyvyn tukemiseen on hyvä kiinnittää erityistä huomiota työterveyshuollossa myös silloin, kun he kärsivät äänihäiriöistä ja stressistä ja heidän työpaikkansa sisäympäristössä on puutteita.

AVAINSANAT: Ääni, äänioireet, äänihäiriöt, opettaja, stressi, työhön liittyvä stressi, sisäympäristö, sisäilma, koettu, tekninen arviointi, työkyky, sairauspoissaolo

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Abbreviations

ANOVA	One-way analysis of variance
aOR	Adjusted odds ratio
aRR	Adjusted relative risk
BFI-2-S	Big Five Inventory-2 questionnaire
CI	Confidence interval
IA	Indoor air
IAQ	Indoor air quality
ICQ	Indoor climate quality
IEQ	Indoor environmental quality
JCQ	Job Content Questionnaire
MM 040	Örebro Miljö Medicin questionnaire
n_b	Number of school buildings in the present thesis
n_t	Number of teachers in the present thesis
OAJ	The Trade Union of Education in Finland
OR	Odds ratio
p	Calculated probability
PIAQ	Perceived indoor air quality
PIEQ	Perceived indoor environmental quality
Q_1	Lower quartile
Q_3	Upper quartile
RR	Relative risk
r_s	Spearman's correlation
THL	The Finnish National Institute of Health and Welfare
TSCSS	Teacher Stress and Coping Strategies Surveys
uRR	Unadjusted relative risk
VAPP	Voice Activity and Participation Profile
VHI	Voice Handicap Index
VHI-10	The shortened version of the Voice Handicap Index
VoiSS	Voice Symptom Scale
VPQ	Vocal Performance Questionnaire
V-RQOL	Voice-Related Quality of Life Measure

WAI	Work Ability Index
WAS	Work Ability Score
WHO	World Health Organization

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Vertanen-Greis H, Löyttyniemi E, Uitti J. Voice Disorders are Associated with Stress among Teachers: A Cross-Sectional Study in Finland. *Journal of Voice,* 2020; 34(3): 488.e1-488.e8.

II Vertanen-Greis H, Löyttyniemi E, Uitti J, Putus T. Self-reported Voice Disorders of Teachers and Indoor Air Quality in Schools: A Cross-Sectional Study in Finland. *Logopedics Phoniatrics Vocology*, 2021; Jul 28:1-11. Epub ahead of print.

III Vertanen-Greis H, Löyttyniemi E, Uitti J, Putus T. Work Ability of Teachers Associated with Voice Disorders, Stress, and the Indoor Environment: A Questionnaire Study in Finland. *Journal of Voice*, 2020; Oct 8: S0892-1997(20)30366-0. Online ahead of print.

IV Vertanen-Greis H, Löyttyniemi E, Uitti J, Putus T. The Interaction between Stress at Work and Voice Disorders for Work Ability of Teachers. *Submitted to Journal of Preventive Medicine and Hygiene*.

1 Introduction

Voice is the primary working tool for a teacher. However, voice symptoms—hoarseness, voice breaks, aphonia, a strained voice, throat clearing, a pain around the larynx—are more prevalent in teachers than in other occupations (Cantor Cutiva et al., 2013) and are two-to-three-fold more prevalent in teachers than in the general population (Martins et al., 2014). Moreover, the trend has been increasing (Simberg et al., 2005). Voice disorders have not only long been known as one of the major occupational dangers of teaching (Mattiske et al., 1998), but they may also negatively affect learning, as the poor quality of a teacher's voice can interfere with the pupil's ability, because they have to concentrate on processing the voice instead of the task (Imhof et al., 2014; Lyberg Åhlander, Haake, et al., 2015). Even though teachers, in general, have less absence due to sickness than occupations like office workers and health care employees (Cantor Cutiva & Burdorf, 2015; Nusseck et al., 2018), the teachers with voice problems have clearly more sick leave than the vocally healthy ones (Lyberg Åhlander et al., 2011). They also burden the health care system. As noted, teachers formed only 4% of the US workforce but represented 20% of the voice-clinic patients (Titze et al., 1997).

In practice, a teacher's voice problems are often addressed with "every teacher has hoarseness" rather than "what could we do for it?" As a result, two out of three Finnish teachers have never had any vocal training during their career or teacher training studies (Ilomäki et al., 2005). However, as early as during the ninth century, physician Rhazes the Experienced in Baghdad described hoarseness and voice disorders and recommended voice training (von Leden, 2017). In recent decades, attention has then been paid to vocal training in academia (Mattiske et al., 1998; Nusseck et al., 2018; Simberg et al., 2006; van Houtte et al., 2011), however, not as much in practice. When Aristotle commented on the voice, he did not refer to training but rather recognized its close relationship with emotions (Sataloff, 2017). Over a period of time, emotions have merely been understood to associate with voice.

Stress, meaning that when one is tense or restless, has become a main contributor to voice disorders. Today, stress is noted as one of the major dangers for an occupational voice (Holmqvist-Jämsén et al., 2017a; Rantala et al., 2012; Simberg et al., 2005; Vilkman, 2004), and it is also been found to associate with a decreased

work ability, whether voice problems were presented or not (Kyriakou, 2011; Schouteten, 2017). In addition to stress, vocal load and the indoor environmental aspects, such as air humidity, impurities in the air, and noise are among the main contributors to voice disorders (Dejonckere, 2001b; Martins et al., 2014). The extensive use of the voice is even a higher risk for teachers' voice disorders than noise (Byeon, 2019). As noted by clinicians, patients of voice clinics often report indoor environmental complaints such as dry air (Dejonckere, 2001b; Lyberg Åhlander et al., 2014), and a higher amount of absence due to sickness is also found to associate with a poor indoor air quality (Ervasti et al., 2012).

The working environment has changed over the decades. In Swedish-occupied Finland, during the first school order of year 1571, singing was one of the three compulsory subjects and supported the correct use of a voice through perfect acoustic properties, as the schools were a part of a church or a monastery. Subsequently, the acoustic conditions have deteriorated, and active discussion has been started for the need to improve acoustics in schools. However, more discussion has been directed towards the indoor environmental problems in schools. In Finland, the majority of these problems occur in primary and secondary school buildings (Korhonen et al., 2018), and the most common problems are not only noise but also stuffy or dry air, dust, and insufficient ventilation (Putus et al., 2017; Tähtinen et al., 2020). These complaints are precisely those indicators that are found to associate with vocal function (Cantor Cutiva et al., 2013; Lyberg Åhlander et al., 2011; Rantala & Sala, 2015). In a crowded school building with intense activities, the indicators present through various interactions, rather than singly, and with large individual differences in regards to the occupants (Bayer et al., 2000; Corgnati & da Silva, 2011; Vilkman, 2004; Wolkoff, 2018a). In addition to questionnaires that are widely used for studying both indoor environmental problems and voice disorders, deficiencies in the IEQ are evaluated by using walk-through and technical measures. Overall, while challenges to evaluating voice and indoor air quality have been reported (Laukkanen et al., 2008; Lyberg-Åhlander et al., 2015; Mendell & Kumagai, 2017), insufficient ventilation and dry air, in addition to the obvious noise, have recently suggested a link between voice problems specifically in teachers and a school's indoor environment (Lin et al., 2020; Medeiros & Vieira, 2019; Wargocki et al., 2020).

Recently, well-being has shifted to be one of the employer's responsibilities rather than a personal endeavor (McIntyre et al., 2017). Findings that are a cause of concern have also been presented during recent decades due to teacher-turnover rates, and this has been identified as a major concern in educational research and policy analysis (Harris & Adams, 2007) and also by the OECD (Galton & MacBeath, 2008). Teachers face enormous challenges in their work, such as pupil misbehavior, reforms, a heavy workload, and the imbalance between demands and resources

(Byeon, 2019; Ervasti et al., 2012; Galton & MacBeath, 2008; R. A. Karasek, 1979; Kauppinen et al., 2013; Kyriacou, 2011; Santavirta et al., 2007). Overall, voice symptoms, stress, and a poor indoor environment appear to decrease work ability in teachers, and associations are reported between all these variables. However, there is a lack of knowledge of how these three variables are taken into consideration in relation to teachers' work ability. This thesis presents epidemiological data on 1 198 Finnish primary and secondary school teachers that focus on voice disorders in teachers, stress at work, and the IEQ, and all of their associations with work ability. The novel findings could be utilized as a basis for new theoretical frameworks to support teachers in their valuable work.

2 Review of the Literature

Voice disorders are more frequent in teachers than in other occupations, yet a well-functioning voice is a basic tool for the teaching profession. Voice problems present in various ways, such as hoarseness, throat clearing, or a voice that tires easily. There are thus multiple definitions of voice disorders, and their prevalence among teachers show a clear variation. A major danger for having an occupational voice is stress, and there is also limited information on the association between IEQ and the quality of teaching. Overall, voice symptoms, stress, and indoor environmental problems appear to decrease the work ability in teachers. However, there is a lack of knowledge of how these three variables are taken into consideration in relation to teachers' work ability.

2.1 Voice Disorders in Teachers

In a review (Cantor Cutiva et al., 2013), the prevalence of voice problems (i.e., laryngitis, hoarseness, voice breaks, aphonia) was found to be from 17% to 57%, and they are the more prevalent in teachers than in other occupations. Compared to the general population, the difference is even more distinct. In a review (Martins et al., 2014), voice disorders were two-to-three-fold more prevalent in teachers at 20–50% or even 80% than in the general population at 6–15%. Teachers' voice problems also increase the demand in health care, as in the US, teachers represent 4% of the workforce but 20% of the voice-clinic load (Titze et al., 1997). In general, the studies related to voice disorders are cross-sectional, questionnaire surveys utilizing a wide range of sample sizes and time periods. Altogether, 58% of US teachers reported adverse vocal symptoms during their lifetime (Roy et al., 2004b), and in Europe, a lifetime prevalence of voice disorders was found to be 51% (Angelillo et al., 2009; van Houtte et al., 2011). In contrast to the cross-sectional studies, a longitudinal study (Simberg et al., 2005) of Finnish teachers revealed that vocal symptoms increased from 5% to 20% over a 12-year period. To compare, the prevalence of voice disorders in the treatment seeking population is approximately 1% and is more common in females than in males at 1.2% versus 0.7%. Voice problems are also more common during aging and common in the over 70-year old population. (Cohen et al., 2012)

As Table 1 shows, the self-reported studies have had a wide range of results. Similarly, clinical findings have led to varied conclusions. Abnormal findings occurred in 46 out of 80 teachers in clinical examinations in South America (58%) (Tavares & Martins, 2007). Also in Spain (n = 905) (Preciado-López et al., 2008), the prevalence of self-assessed voice disorders was 57% compared to a clearly lower prevalence of clinical findings being vocal overstrain at 18%, nodular lesions at 14%, and hyperfunctional dysphonia at 8%. In Finland, 14% of the 78 teachers had clear clinical changes and 37% had mild changes, and these findings did not associate with self-reported vocal symptoms with 32% having two or more weekly symptoms (Ilomaki et al., 2009). When compared to different teaching levels, 11% of day care teachers had clear clinical findings (Kankare et al., 2012), and primary school teachers reported a significantly higher score of voice symptoms than kindergarten teachers and also in differences in acoustic measures between these two groups (Munier et al., 2020). Regarding occupational differences, laryngoscopic findings (e.g., vocal nodules or laryngitis) occurred significantly more often in day care teachers (29%) than nurses (7%) (Sala et al., 2001).

Voice problems are defined in multiple ways, and this consequently results in inconsistent findings (Cantor Cutiva et al., 2013). A medical definition is based on disorders in the vocal tract (Sala & Rantala, 2019), while from a functional viewpoint, voice problems occur "any time the voice does not work, perform, or sound as it normally should, so that it interferes with communication" (Roy et al., 2004b) (p. 283). Voice problems can also be compared to what is abnormal as in the quality, pitch, loudness, or flexibility resonance, and/or the duration is different than in those with the same age and sex (Aronson & Bless, 2009; *Definitions of Communication Disorders*, 1993). In the studies concerning moisture damage and health, voice problems are rarely addressed and usually treated as a respiratory symptom and defined as hoarseness (Patovirta et al., 2004a; *WHO*, 2009). In an intervention study (Patovirta et al., 2004a), hoarseness was significantly more common for teachers in moisture-damaged school buildings than in the reference building. As recently found, the occurrence of hoarseness was 32%, and it was significantly associated with the time spent in the work place (Putus et al., 2017).

Table 1. Major publications on the epidemiology of voice problems in schoolteachers and associated variables.

Study	Definition of voice disorders	Sample, n_t (sex)	Prevalence (time period)	Associated variables
E. Smith et al. (1997) (US)	Having a voice problem	242 T + 178 NT (FM)	15% T vs. 6% NT (current)	F, old age, years of working
E. Smith et al. (1998b) (US)	Having had a voice problem	554 T + 220 NT (FM)	32% T vs. 1% NT (lifetime)	F, teaching PE
Roy et al. (2004b) (US)	Voice disorder: The voice does not work, perform, or sound as it normally should, so that it interferes with communication	1 243 T + 1 288 NT (FM)	58% T vs. 29% NT (lifetime) 11% T vs. 6% NT (current)	F, age 40–59
Kooijman et al. (2006) (Netherlands)	Voice problems: Experienced any voice complaints	1 878 T (FM)	59% (during the career)	F, problems in neck and shoulders, large group size, stress, temperature changes
Thomas et al. (2006) (Netherlands)	Voice problems: Experienced any voice complaints	82 T + 454 student T (F)	37% T vs. 17% NT (current) 54% T vs. 37% NT (12 mo))	Stress, work pressure
De Jong et al. (2006) (Netherlands)	Voice problems: Experienced voice complaints (VHI)	1 878 T + 239 NT (FM)	18% T (current) 34% T (12 mo) 58% T (lifetime) (VHI significantly higher for T and those with VC)	F, young age (median 45 vs. 47)
de Medeiros et al. (2008) (Brazil)	Dysphonia: Daily probable (vs. absent/possible) fatigue when speaking or loss of voice quality	2 103 T (F)	15% (2 weeks)	Noise, poor ventilation, depression and anxiety, medication for psychiatric and related conditions
Munier & Kinsella (2008) (Ireland)	Voice problems	304 T (FM)	27% (current)	

Study	Definition of voice disorders	Sample, n_t (sex)	Prevalence (time period)	Associated variables
Angelillo et al. (2009) (Italy)	Vocal problem (symptoms such as hoarseness)	504 T + 402 NT (FM)	9% T vs. 3% NT (current) 51% T vs. 26% NT (lifetime)	F
Da Costa et al. (2012) (US)	Voice problem or hoarseness	237 T (FM)	22% (current) 58% (lifetime)	F, > 45 years old
Lyberg Åhlander et al. (2011) (Sweden)	Voice problems sometimes/often/always	467 T (FM)	13%	Poor acoustic, low humidity, dry air
Chen et al. (2010) (Taiwan)	Voice problem often/always (symptoms such as tired voice)	117 T (FM)	50%	Infection, stress, anxiety, medication
Chong & Chan (2010) (Hong Kong)	Unspecified voice disorder	1 710 T (FM)	74% (mo)	F, teaching PE
van Houtte et al. (2011) (Belgium)	Voice disorder: Voice did not work, perform, or sound as it usually does and interfered with communication	994 T + 290 NT (FM)	51% T vs. 27% NT	F
Behlau et al. (2012) (Brazil)	Voice disorder: Voice did not work, perform, or sound as it usually does and interfered with communication	1 651 T + 1 614 NT (FM)	12% T vs. 8% NT (current) 63% T vs. 36% NT (lifetime)	F
Sampaio et al. (2012) (Brazil)	VHI-10: Moderate/severe handicap (11–40 points)	4 496 T (FM)	21%–29%, depending on the vocal effort	F, vocal effort, noise, heartburn, rhinitis

Abbreviations: D: dysphonia; F: female; H: hoarseness; KT: kindergarten teachers; lifetime: lifetime prevalence; M: males; NT: non-teachers; n_t: number of teachers; PE: physical education; T: teachers; unspecified: unspecified recall period; VC: voice complaints; VD: voice disorder; VP: voice problems; vs.: versus; VS: voice symptoms; 6 mo: 6-month prevalence; 12 mo: 12-month prevalence.

Voice problems in teachers is, however, an occupational question (Vilkman, 2004), as teachers tend to suffer from voice problems during the term but not during the vacation (Jónsdóttir, 2003; Sala et al., 2001). The term "occupational voice" is referred to those occupations, where a healthy and strong voice is needed to tolerate the work-related loading of a voice, like in teachers and other instructors, priests, and telemarketers. To compare, singers and actors need merely a clear, pleasant, and high-quality *professional voice*. (Casper, 2001; Sala & Rantala, 2019) From that point of view, voice disorder is simply defined as "an individual's voice does not meet the occupational criteria and demands" in Finland (Vilkman, 2004) (p. 234). The "demands" refer to voice quality and vocal requirements, and in the teaching occupation, vocal endurance is of high significance, whereas the way a voice sounds is not as essential as, for example, in professional singers (Vilkman, 2004). Then, main physical attributes of vocal loading are the number of vocal fold vibrations per second, the sound level of voice, and the duration of voicing. In a comparative study between day care teachers and nurses, it was found that the teachers use their voices for longer periods of time, with higher voice levels, in more noise, and in poorer acoustics than nurses. All these issues are associated with voice symptoms. (Sala et al., 2001)

A questionnaire is a relevant instrument to collect epidemiological data on voice disorders. The Voice Handicap Index (VHI) (Jacobson et al., 1997) and the Voice Activity and Participation Profile (VAPP) (Ma & Yiu, 2001) are generally used in voice assessments (Francis et al., 2017). They are available in Finnish (Alaluusua & Johannson, 2003; Sukanen et al., 2007), whereas the other widely used questionnaires, the shortened version of the VHI (VHI-10), the Voice Symptom Scale (VoiSS) (Deary et al., 2003), the Voice-Related Quality of Life Measure (V-RQOL) (Murry et al., 2004), and the Vocal Performance Questionnaire (VPQ) (Deary et al., 2004) were not available in Finnish at the time that the present study was performed. The VHI and the VAPP are rather extensive surveys with 28 and 30 items.

The voice screening questionnaire, developed in Finland by Sala and Simberg (Sala et al., 2001; Simberg et al., 2001), consists of only 6–11 questions. The initial version consisted of six voice symptoms; *throat clearing*, *voice tires easily*, *hoarseness*, *sore throat or globus*, *voice breaks*, *difficulty in being heard*, and *aphonia*, and a *voice disorder* was defined as when the subjects had a minimum of two voice symptoms occurring at least weekly during the previous 12 months and also had clinically assessed changes in their vocal folds (Sala et al., 2001). Since the questionnaire was developed, it has been utilized in multiple studies in Finland with a variety of symptoms. Ohlsson et al. (2012) named the 6-item questionnaire as Screen6, and the current version with 11 questions is named as Screen11 (Zenger, 2019). In the present thesis, the term "screening questionnaire" refers to all these

screening questionnaires in general instead of a certain version. The different versions are called according to the number of questions being Screen6, Screen7, Screen8, and Screen11.

In a study where 478 teachers and 95 nurses were compared (Pekkarinen et al., 1992) and also in a 12-year follow-up study of 241 teachers (Simberg et al., 2005), the first version of the screening questionnaire, Screen6, was utilized. In the second version of Screen6, the symptom *aphonia* was placed with *throat clearing or coughing*. The second version of Screen6 has been the most used screening questionnaire, and it has been utilized in studies of 1 728 twins (Simberg et al., 2009b, 2015; Holmqvist et al., 2013; Nybacka et al., 2012); in 889 priests (Hagelberg & Simberg, 2015); in 217 children aged 6–10 years (Kallvik et al., 2015); in 109 soccer coaches (Fellman & Simberg, 2017); and in 315 choir singers (Ravall & Simberg, 2020). It has also been used in Sweden among 1 250 (Ohlsson et al., 2012) and 400 student teachers (Ohlsson et al., 2015), and in 968 student teachers in Norway (Greve et al., 2019). The second version of Screen6 was also assessed as having a significant association with the VHI (Greve et al., 2019). While the screening questionnaires were very similar among the studies, there were some differences regarding the terms used. All differences between the screening questionnaires are presented in Table 2. In the Screen7, a seventh symptom, *aphonia*, was added. Screen7 was utilized to assess voice disorders in 226 student teachers (Simberg et al., 2000) to compare 262 day care teachers and 108 nurses (Sala et al., 2001), 49 students (Simberg et al., 2006; Simberg et al., 2009a), and 39 teachers (Rantala et al., 2012, 2018). Screen8 was complemented with a symptom *morning hoarseness*, and it was used only in a sample of 76 student teachers (Simberg et al., 2001). In some variations of the screening questionnaires, two different symptoms have been combined, such as *voice becomes strained or tired*. This concern is addressed in the current version, Screen11, where the symptoms have been separated into different questions. Screen11 was developed after the survey for the present thesis was performed, and it is currently under validation (Zenger, 2019). The developing process for the questionnaire has been previously described by the authors (Simberg & Sala, 2008).

Multiple individual variables play a key role in occupational voice disorders. One of them, stress, is repeatedly noted as being associated with voice problems in teachers. In the next chapter, the association is introduced in more detail.

Table 2. The comparison of the screening questionnaires.

Version	Prevalence of voice disorders*	Morning hoarseness	Voice strained or tires	Voice low or hoarse	Voice breaks	Difficulty in being heard	Throat clearing or coughing	Pain, tension, or a lump in the throat	Aphonia
Screen6, version 1	Increased from 5% to 20%		Voice tires easily	Hoarseness (without a cold)	Voice breaks	Difficulty in being heard		Sore throat or globus	Aphonia
Screen6, version 2	In teachers, only different symptoms assessed; Teacher students: 14%–17%; Priests: 27%; Soccer coaches: 28%		Voice (strained or) tires**	Voice (low or) hoarse / Hoarseness without a cold	Voice breaks (while talking)	Difficulty in being heard	Throat clearing or coughing	Sore throat or globus / Pain or a lump / Tension in the throat	
Screen7	In schoolteachers, only different symptoms assessed; Day care teachers: 37%		Voice tires easily / strained	Voice low / Hoarse	Voice breaks	Difficulty in being heard	Throat clearing or coughing	Pain or a lump in the throat / Sore throat or globus	Aphonia
Screen8	-	Morning hoarseness	Voice strained or tires	Voice low or hoarse	Voice breaks	Difficulty in being heard	Throat clearing or coughing	Pain, tension, or a lump in the throat	Loss of voice
Screen11	-		• Strained • Tired voice***	• Hoarse • Low voice	Voice breaks	Difficulty in being heard	• Throat clearing • Coughing	• Tension • Pain • Lump in the throat	

* A minimum of two voice symptoms occurring at least weekly during the previous 12 months. ** The differences among the studies are shown with parentheses and slashes. *** The different voice symptoms are separated with a "•."

2.2 Voice and Stress at Work

The stress reaction—a compensatory reaction when one senses a disruption to the physiological and mental homeostasis (Goldstein & McEwen, 2002)—is universal and present in all voice usage (Van Puyvelde et al., 2018). As found in a study in the general population (n = 1 728), the subjects with stress symptoms had more often vocal symptoms, and 45% felt nervous or tense when they were required to talk (Holmqvist et al., 2013). Stress is associated with physiological systems such as endocrine and autonomic nervous responses and changes in blood pressure (Bellingrath & Kudielka, 2017). For example, the trapezius muscle activity associates with the elevated cortisol levels that is involved in slow stress reactions (Lundberg, 2005, 1994). The increased muscle tension is also associated with vocal symptoms, as speaking is muscle work (Baker, 2008), and also the higher cortisol levels associate with voice symptoms (Holmqvist-Jämsén et al., 2017a). An additional link between voice and stress is respiration, as it is the driving force of both the processes of stress and voice production (Dietrich & Verdolini, 2012; Pattyn et al., 2010; Vlemincx et al., 2011).

Related to work, stress can be defined as work pressure or demands (Klassen & Chiu, 2011), emotional or behavioral experience caused by work (Kyriakou, 2001, 2011), or a disagreement between the work demands and the worker's resources (Lazarus, 1966). From the perspective of occupational health, the focus is on the organization's goal to support teacher's health and well-being rather than personal flaws (McIntyre et al., 2017). One of the best known work-stress theories is the Job Demand-Control Model (JDC), where the psychosocial workload is defined by the relationship between job demands and resources (Karasek, 1979; Karasek & Theorell, 1990). The model was further developed by including the social relationships in the workplace. Apart from this, the common elements in the definition of stress at work are an imbalance between support and individual needs as well as an imbalance between demands and individual abilities (Cox et al., 2000; French et al., 1981). Stress may have multiple consequences in work, such as burnout, indifference towards the work, or lowered ability to cope effectively in the role (Travers, 2017).

Stress is very present in teaching work (Kyriakou, 2001), and the prevalence of work-related stress has varied from approximately 25% to 80% (Travers, 2017). Recently, the prevalence of stress was found to be as high as 30% in Finnish teachers (Putus et al., 2017). In a Cochrane review (Naghieh et al., 2015), the evidence indicated multiple association between work and stress in teachers, such as heavy workload, a poor IEQ, and pupil behavior. However, it is also argued that teachers suffering from exceptional amounts of psychological distress is less conclusive than often assumed (van Droogenbroeck & Spruyt, 2015). Comparing to other occupations, studies in the UK show that approximately 20% of the general

population had high levels of stress at work in a random sample (n = 17 000), and the major groups in the high stress level categories were teachers, nurses, and managers (A. Smith et al., 2000). In another study, teaching was the second most stressful occupation, next to occupations in the banking and finance industry (*Work Smarter*, 2000). Then, teachers' well-being was found to be worse than average, together with occupations like ambulance workers, prison officers, and police officers (Johnson et al., 2005).

Stress is also mentioned as one of the major dangers for one's occupational voice (Holmqvist-Jämsén et al., 2017a; Rantala et al., 2012; Simberg et al., 2005; Vilkman, 2004). A follow-up study (Simberg et al., 2005) indicated that inconvenience variables, such as noise, increased significantly during 12 years. The authors suggested that misbehaving pupils may cause the increased noise, and this might also cause stress and exacerbate voice disorders (Chen et al., 2010; Kooijman et al., 2006; Sliwinska-Kowalska et al., 2006; van Houtte et al., 2012). Stress was found to be an even higher risk for voice disorders than the duration and intensity of voice use (Kooijman et al., 2006), although extended voice use is concluded to be a causative factor for voice problems in teachers (Morton & Watson, 2001). In addition to teaching work, stress is associated with voice symptoms in other vocally demanding occupations, where stress is a part of the job. In a study among soccer coaches, a significant association was found between stress and vocal symptoms, and 32% of the subjects reported stress as associating with the coaching tasks (Fellman & Simberg, 2017). In another study, 12% of priests reported voice symptoms having an impact on mood (Hagelberg & Simberg, 2015).

Work-related stress is mostly measured through a cross-sectional study design using a questionnaire (Skaalvik & Skaalvik, 2017). One of the most frequently used and validated questionnaires is the Job Content Questionnaire (JCQ) (Karasek et al., 1998). This 49-item JCQ evaluates job demands, social support, and decision-making. A shorter questionnaire, the Big Five Inventory-2 (BFI-2-S) questionnaire, includes 15 items and covers neuroticism, extroversion, openness to experience, agreeableness, and conscientiousness (Soto & John, 2017). As stress in teachers is a very well-known phenomenon, there are special questionnaires that are performed for teachers such as the Teacher Stress and Coping Strategies Survey (TSCSS), which measures the sources and means of stress with 40 items (Richards, 2012). In Finland, the Occupational Stress Questionnaire was developed for occupational health use (Elo et al., 1992). It was based on the psychological theory of work stress (Frankenhaeuser & Gardell, 1976; Kagan & Levi, 1974), and there were also dimensions related to job demands, control, and social support (Karasek & Theorell, 1990). Initially, the questionnaire involved 56 items, and different versions were used to develop a single-item questionnaire (Elo et al., 1998). While the questionnaire refers to the general experience of stress, not to work-related stress, it

is validated for occupational use and also widely utilized in population studies (Elo et al., 2003).

2.3 Voice and Indoor Environmental Quality

Indoor environmental quality (IEQ) is defined as *indoor air*, *thermal*, *acoustic*, and *lighting conditions* and a part of it, indoor climate quality (ICQ) includes *indoor air quality* and *thermal* conditions. Indoor air quality (IAQ) then refers objectively to contaminants in the air, deficiencies in ventilation, and humidity, while the perceived indoor air quality (PIAQ) focuses on the related perceptions such as stuffy or dry air, odors, dust, and insufficient ventilation. The perceived indoor environmental quality (PIEQ) refers to a subjective evaluation of the indoor environmental quality such as the experiences of draught, temperature circumstances, stuffy or dry air, ventilation, odors, dust, noise, and lighting conditions. (ASHRAE, 2010; Asumisterveysasetus, 2015; Bayer et al., 2000; Corgnati & da Silva, 2011)

Poor IEQ, together with extensive voice use, is a hazardous combination for the voice (Vilkman, 2004). The results of a twin study (n = 1 728) (Simberg et al., 2009b) suggested that in a voice-demanding occupation, the etiology of vocal symptoms may be more environmental than genetic, and a further study of the same sample (Nybacka et al., 2012) found that the symptom, the *voice becomes strained or tires*, is associated only with the environment. The term "environment" referred to whether the environment in which the twins grew up was shared or not but still indicated the possible effect of the indoor environment, as well. Some studies have disagreed about the association with the indoor environment (Kooijman et al., 2006; Sliwinska-Kowalska et al., 2006). Nevertheless, the evidence of the association between a poor IEQ and voice symptoms is mostly based on self-reported data, either both voice and IEQ or them separately evaluated (Cantor Cutiva et al., 2013). Exposure to such conditions as dry air, irritations, or temperature changes is found to associate with voice problems in teachers (Houtte et al., 2012; Rantala et al., 2012), however, there are inconsistent findings regarding the association between temperature and voice symptoms (Cutiva & Burdorf, 2016; Kooijman et al., 2006; Lyberg Åhlander, Rydella, et al., 2015; van Houtte et al., 2012). Insufficient ventilation and dryness are reported to associate with voice symptoms (Cantor Cutiva et al., 2013), and inadequate ventilation is suggested to multiply the risks of voice symptoms even more (Godwin & Batterman, 2007; Rantala et al., 2012). Voice symptoms in teachers are also associated with the IEQ, noise, or effect on the voice of poor indoor air indicators, such as ventilation problems, low humidity, and stuffy air (Cantor Cutiva et al., 2013; Lyberg Åhlander et al., 2011; Rantala & Sala, 2015).

As speakers breath mostly through the mouth, indoor air exposures allow transmission directly to the larynx (Wolkoff, 2018b). The epithelium, the outermost

layer of the vocal folds, protects the vocal folds during acute pollutant exposures, whereas longer exposures may disturb it (Levendoski et al., 2014). Clinically, different aspects of the IAQ are suggested to associate with both the changes in the voice based on the deterioration of mucosa in the airways and vibratory properties of the vocal folds and also with vocal cord hyperfunction (Vilkman, 2004; Vintturi et al., 2001; Wolkoff, 2018a). Hyperfunctional changes in the voice are more prevalent in dry air (Vintturi et al., 2001). As found in an experimental study with sheep larynges (Hemler et al., 2001), dry air resulted in a stiffer and more viscous cover of vocal folds than humid air. Dryness may also increase the phonation threshold pressure (Verdolini et al., 1994). In an *in vitro* model, decreased hydration raised the threshold of oscillation, while increased hydration lowered it (Finkelhor et al., 1988). In a study among 20 young amateur singers, water intake together with vocal rests resulted in significantly longer singing sessions than being without any water or rest, and water intake and vocal rest had also significant differences in measured voice quality (Yiu & Chan, 2003). Water intake is the most important for those with vocal fatigue (Sivasankar et al., 2008). The perceived dry air is not only a result of low humidity but also contributed by air pollutants, which together aggravate the protective mucous layer in the airways and may lead to a hoarse and weak voice (Geneid et al., 2009; Wolkoff, 2018a). In the school environment, the IAQ aspects are presented in different combinations rather than separately with various interactions in addition to large differences in the individuals (Bayer et al., 2000; Corgnati & da Silva, 2011; Vilkman, 2004; Wolkoff, 2018a). Whereas voice problems are a question of occupation for teachers as a whole, they should also be seen in relation to their work environment (Lyberg Åhlander et al., 2011).

While respiratory symptoms are associated repeatedly with problems in the IAQ (Haverinen-Shaughnessy et al., 2012; Sauni et al., 2015), less attention has been paid to voice symptoms. In addition, recent studies have suggested concerning findings between voice problems and the IEQ of school buildings (Lin et al., 2020; Medeiros & Vieira, 2019; Wargocki et al., 2020), and specific studies have been conducted to study the association between voice problems and the IAQ, utilizing external assessments of the IAQ in addition to the PIAQ (Cantor Cutiva et al., 2013). In addition, it was recently estimated that the majority of indoor air problems in Finland occurred in the actual buildings of primary and secondary schools (Korhonen et al., 2018).

The association between voice symptoms and IEQ can be evaluated by using questionnaires, assessments based on documents, walk-throughs, microbiological samples, and other technical measures. Some authors have stressed that IEQ should be evaluated as a whole, while others have suggested that simple metrics—that avoid the complex threshold defined between minor and major damage—can be seen as being amongst having the strongest associations with health outcomes (Mendell &

Kumagai, 2017). Nevertheless, it is recommended to validate the questionnaire data with external evaluation of buildings (Haverinen-Shaughnessy et al., 2012). As mentioned in the previous studies, there are challenges to finding relevant methods for assessing the IAQ and voice problems (Laukkanen et al., 2008; Lyberg-Åhlander et al., 2015; Mendell & Kumagai, 2017).

In Finland, the questionnaires are mostly based on the Örebro Miljö Medicin (MM) questionnaires (Andersson, 1998) that were developed in Sweden and are also used in other Nordic countries. The MM questionnaires have four parts being the work environment, the work arrangements, the allergy history, and the symptoms related to IEQ. Another widely used questionnaire is the Tuohilampi questionnaire that was created based on the MM questionnaire. The questions regarding the IEQ complaints are broadly the same among these questionnaires. The Tuohilampi questionnaire is more extensive and includes four options to be answered in a recall period of 12 months compared to the MM questionnaire that is more compact with three options and a 3-month recall period. In the present study, the MM 040 questionnaire for school personnel was utilized (Andersson et al., n.d.).

2.4 Other Variables Associating with Voice

Vocal load is one of the major variables associating with voice disorders in teachers (Cantor Cutiva et al., 2013). It has been assessed in multiple ways in previous studies, for example, by asking teachers about their number of working years, teaching hours per day or per week and the use of the voice during leisure time or by assessing noise at work. Vocal load may differ between the teaching levels and during the workday, as schoolteachers had more throat fatigue after their workday (Laukkanen et al., 2008) and more voice problems than kindergarten teachers (Munier et al., 2020). Female sex is associated with voice disorders in general, being a potential confounding factor in the present thesis (Byeon, 2019; Dejonckere, 2001a). The main reason for the sex differences are physiological, based on the smaller size of the larynx in females (Dejonckere, 2001a). Thus, identical phonation times cause clearly more vibrations in female than in male speakers (Vilkman, 2004). Age is another main risk variable in health studies but seems to remain an inconsistent variable in voice studies. Other studies have found clear associations between voice symptoms and age, whereas others have not found any evidence of such a relationship (Da Costa et al., 2012; de Jong et al., 2006; Ilomaki et al., 2009; Kankare et al., 2012).

Asthma is a hazard for the voice, because of mucosal changes caused by obstructive respiratory disease and the side effects of the inhaled corticosteroids (Hackenberg et al., 2010). This hazard is independent of age, sex, or any other background variable. In addition, allergies can affect the voice, as thick and sticky

mucus may interfere with vocal fold vibration (Geneid et al., 2009; Simberg et al., 2009a; Spantideas et al., 2019). Reflux disease, the reflux of gastric contents onto the upper respiratory tract, is associated with both voice symptoms and stress. Although a clear relationship exists between reflux disease and the voice, the nature of that association remains unclear (Devadas et al., 2017; Schneider et al., 2016). This relationship was also assessed in the screening questionnaire, in which the symptoms *morning hoarseness* and *throat clearing* refer to reflux (Sala et al., 2001).

2.5 Work Ability in Teachers

The term "work ability" consists of different dimensions, such as health and functional capacity, work requirements, and the working environment (Tengland, 2011). Work ability can also be defined through work disability that highlights the role of the organization and occupational health care (Loisel, 2009). Previous studies have shown that 43% of teachers report that they have good work ability (Vedovato & Monteiro, 2014). The study was conducted with the Work Ability Index (WAI) that was designed in Finland to collect follow-up data from municipal employees (Tuomi et al., 1997). The WAI is a multifaceted instrument focusing on job demands, current illnesses, work disability, absence due to sickness, prognosis of work ability, and mental resources. The WAI as well as its first item, the Work Ability Score (WAS) that assesses current work ability compared with a lifetime best, are used worldwide in clinical practice and in research (Ahlstrom et al., 2010; Guidetti et al., 2018; Ilmarinen, 2009; Jääskelainen et al., 2016; McGonagle et al., 2015; Oakman et al., 2018; Tuomi et al., 1997).

Work ability is closely linked to absence due to sickness. As shown in the data from the German statutory health insurance scheme (Scheuch et al., 2015), employees, who are teachers, in Germany, tend to have less sick leave than employees in social care and health care at 16 versus 20 days. The airways and psychological disorders occurred more likely, whereas cardiovascular, muscular, and skeletal diseases less likely in teachers than in the controls. In Finland, teachers at all levels had less sick leave days per year than nurses in different occupations with 9–19 versus 20–25 days, and also social workers had more absence due to sickness than class teachers, subject teachers, or special education teachers at 14 versus 9–13 days (*Finnish Municipalities*, n.d.).

The association between decreased work ability and voice disorders has been found to be significant (OR = 9.5) (Giannini et al., 2015). According to Roy et al. (2004a), 18% of teachers had missed at least a day, and 3% of teachers had missed more than five days of work during the past year because of voice disorders compared to non-teachers (7% and 1%). The study population consisted of 1 243 US teachers and 1 158 non-teachers of a random sample of individuals, who had never

worked as a teacher or as an instructor. In Germany, 24% of teachers had sick leaves over their career because of voice disorders, and the average was 1.2 days in a year (Nusseck et al., 2018).

2.6 Voice Disorders, Stress, the Indoor Environmental Quality, and Work Ability

In contrast to teachers' sick leave in general, previous studies, globally, have shown that teachers with voice problems clearly have more absenteeism due to sickness compared to their healthy colleagues (Behlau et al., 2012; de Medeiros & Vieira, 2019; Lyberg Åhlander et al., 2011; van Houtte et al., 2011). Swedish schoolteachers with voice problems had four times more sick leave days compared to those without such problems (n = 467) (Lyberg Åhlander et al., 2011). Schoolteachers in Belgium reported twice the number of voice problems than the control group of university administrators and other employees with low vocal loading ($p < 0.001$) (van Houtte et al., 2011). In this study, 25% of the subjects needed clinical care, and 21% had had absence due to sickness because of voice problems. In a large sample of 6 510 teachers (de Medeiros & Vieira, 2019), 18% of sick leave was explained by voice disorders in Brazil. Additionally, in Brazil (n = 354), the teachers, who suffered from voice disorders, more often had poor or moderate work ability. The work ability was assessed by using a Work Ability Index, a tool that is a good predictor of early resignation (Giannini et al., 2015).

As a whole, stress is often associated with decreased work ability, whether voice problems were presented or not (Kyriakou, 2011; Schouteten, 2017). Stress alone was also evaluated to be a reason for sick leave. The association between workplace bullying and subsequent long-term sick leave may be partially mediated by perceived stress (Grynderup et al., 2016; Thorsen et al., 2019). In a study of 4 114 civil servants and hospital employees in Denmark (Grynderup et al., 2016), stress predicted long-term sick leave of 21 days or more, while in another study (n = 17 795) (Thorsen et al., 2019), stress was more often prevalent with sick leave regardless of the length. In the study, the occurrence of work-related stress was as high as 58%.

Previous findings suggested that employees who had a negative perception of their psychosocial work environment had more health symptoms associated with indoor air problems (Lahtinen, 2004). However, recent findings showed contradictory findings, in which office employees experienced slightly more stress but reported less environmental complaints than office workers and health care employees (Tähtinen et al., 2020). In the European OFFICAIR research project, higher satisfaction levels of perceived IEQ were significantly associated with a decrease of work-related stress (Thach et al., 2020). In addition, building characteristics, such as acoustical solutions and a high level of cleaning were

associated with the overall satisfaction and health of the participants (Sakellaris et al., 2016). A high level of sick leave time is also found to associate with a poor IAQ (Ervasti et al., 2012; Rantala et al., 2012). In a register study (Ervasti et al., 2012), it was concluded that teachers working in schools with a poor IAQ had more short-term, being from one to three days, sick leave compared to those in schools with a good IAQ. Insufficient thermal conditions were suggested as having adverse effects on teaching performance (Lin et al., 2020). Furthermore, as ventilation improvement, from 2 to 7.5 in L/s per person, increased the academic performance in pupils by 5%, and the authors suggested that a similar effect might also occur for teachers (Wargocki et al., 2020). In addition, 22 days of absence were reported in the previous year for teachers working in moisture-damaged schools compared to those in a non-damaged building. These teachers only had 2 days of absence on average ($p = 0.015$) (Patovirta et al., 2004a). The findings were consistent, even though some were based on certain indoor air indicators and measured by external specialists (Patovirta et al., 2004a; Wargocki et al., 2020) and the others on varying self-reported environmental variables (Lyberg Åhlander et al., 2011; van Houtte et al., 2012). In a review, it was shown that even though IEQ contributed positively to the academic performance of students, the effect of IEQ on the quality of teaching remained undetermined because of the lack of evidence (Brink et al., 2020).

To summarize this literature review, voice symptoms are more common among teachers than in employees without heavy vocal loading such as nurses and office workers (Cantor Cutiva et al., 2013), and stress is present in teaching-based work, arising from the various demands and lack of resources (Ervasti et al., 2012; Karasek, 1979; Kauppinen et al., 2013; Kyriacou, 2011; Santavirta et al., 2007). Less attention has been paid to the association between voice problems and the poor indoor environment of school buildings, and thus further studies are warranted (Cantor Cutiva et al., 2013; Lin et al., 2020; Medeiros & Vieira, 2019; Wargocki et al., 2020). Voice symptoms, stress, and indoor environmental problems appear to decrease the work ability in teachers, and associations are reported among all these variables. However, there is a lack of knowledge about how these three variables are taken into consideration in relation to teachers' work ability.

3 Aims

The purpose of this thesis was to study the prevalence of voice disorders in teachers, and the associations and interactions among voice disorders, stress at work, poor indoor environmental quality, and the teachers' work ability.

Study I

The aims of the first study were to evaluate (1) the prevalence of voice disorders and (2) the associated variables of voice disorders (i.e., sex, stress, and health symptoms). Stress was hypothesized as being a variable having a substantial association with voice disorders in teachers.

Study II

The aims of the second study were to evaluate (1) the association between voice disorders and perceived indoor air quality, (2) voice disorders and the technically assessed condition of school buildings, and (3) whether there was an agreement between the perceived indoor environmental quality and technical assessment of school buildings. It was hypothesized that both poor perceived indoor air quality and a technically assessed poor condition of school buildings would associate with voice disorders and that there would be an agreement between these two assessments.

Study III

The aim of the third study was to investigate the interaction between voice disorders, stress at work, and perceived indoor environmental quality for self-reported work ability. The hypothesis was that decreased work ability in teachers is associated with voice disorders, stress at work, and poor perceived indoor environmental quality.

Study IV

The aim of the fourth study was (1) to determine the association between stress at work and voice disorders, as a combined variable, and work ability. A further aim

was (2) to study the association between the combined variable and the condition of school buildings. As hypothesized, stress may have a stronger association with work ability as well as with the poor condition of school buildings in the interaction with voice disorders than when evaluated alone.

4 Materials and Methods

Using a sample of 1 198 teachers and a subsample (n_t = 538), voice disorders were assessed by means of a screening questionnaire, and indoor environment assessments were conducted utilizing both perceived and technical evaluations. Stress at work as well as work ability were measured with validated single-item questions. The study design was cross-sectional, as the main purpose was to study the associations and interaction among these variables of interest.

4.1 Study Design and Participants

The focus of the present thesis was on the association between self-reported voice disorders, stress at work, the IEQ, and the work ability. The study flow chart is illustrated in Figure 1.

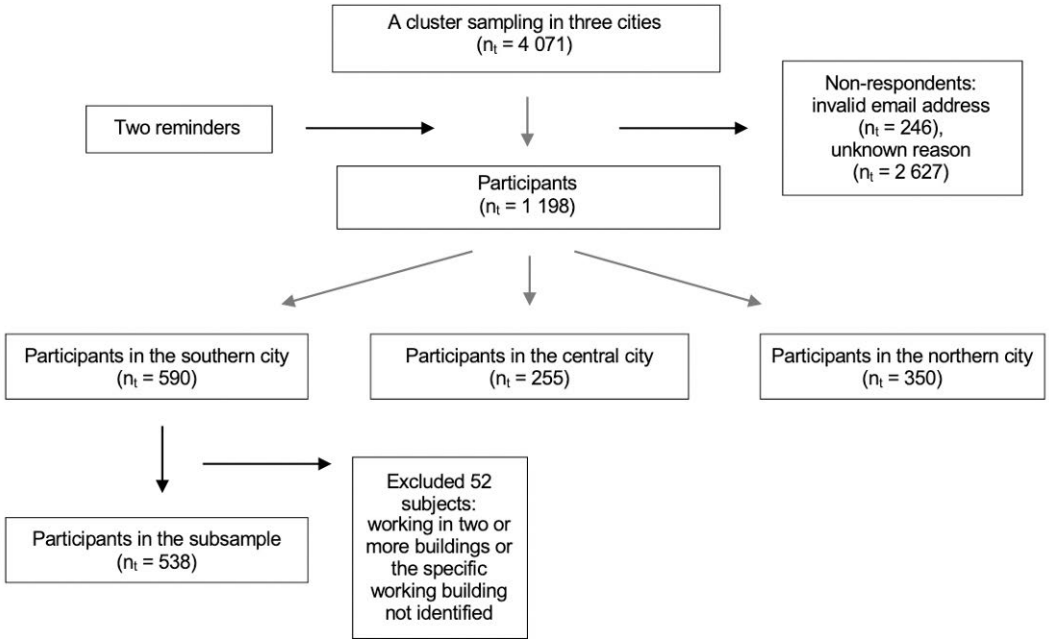

Figure 1. The study flow chart. Abbreviations: n_t: number of teachers.

Initially, a questionnaire study was performed in three cities across Finland during March 2017. The cities are referred to in this thesis as the southern, central, and northern city, as some of the authorities asked to pseudonymized the name of the city. This time of the year was an optimal time in the school year, as it was not during an examination period, and there were no festive occasions or holidays that could have affected teachers' workloads. In addition, the coldest winter season was over, whereas the pollen season had not yet started. The questionnaire, later followed up by two reminders, was sent to the work email addresses of 4 071 teachers in total. To be able to calculate a sufficiently precise 95% confidence interval (i.e., a confidence interval not wider than 10% of a unit) for the prevalence of voice disorders, the aim was to have a sample size of at least 1 500. With an expected response rate of 35%–40%, it was calculated that it would be necessary to request participation from a total sample size of more than 4 000 teachers. Using this information, three main cities across Finland were chosen for cluster sampling. The cluster sampling was chosen, as it enabled the email addresses to be obtained from the employer's register. However, the number of incorrect or invalid email addresses was relatively high (n = 246). The cluster sample also made it possible to have the support and the encouragement for the survey from the leaders of the education departments and the principals. The locations of the cities were chosen to give a geographically representative sample and also to achieve the sufficient sample size of at least 4 000 subjects. The teachers were informed about the survey beforehand and were encouraged to participate by The Trade Union of Education in Finland (OAJ). Moreover, the principals were asked to inform and encourage their teachers to participate in the study. A cover letter was sent separately, with a reminder that the following Webropol email could be found in the spam folder. The presentation of the questionnaire (e.g., question writing, question ordering, visual display) as well as the comprehensibility of the questions were tested with a pilot of 10 subjects. There were two weeks in which to respond.

As the inclusion criteria, only currently employed, Finnish-speaking teachers in primary and secondary schools were included. The primary and secondary school teachers were chosen, as they are a homogenous group of teachers with comparable working circumstances. As vocal demands differ between teachers working in schools with different age levels (Sala et al., 2001), this sample also enabled us to study the differences between primary and secondary school teachers, which are usually reported jointly with, for example, day care teachers or university teachers. The exclusion criteria were teachers, who worked part-time or who taught in more than one school, this was in order to standardize the duration of voice use. In addition, 64 subjects were excluded, as they worked in both secondary and upper-secondary schools. The response rate was 33%. The amount of missing data within the study database was very low, because those subjects, who answered the questionnaire, answered almost every question. The final sample size was 1 198, and

the whole sample was used in Studies I, III, and IV. The dataset from the questionnaires is available online as reported in Vertanen-Greis et al. (2021b). The demographics of the participants are illustrated in Table 3. The participants worked in altogether 129 schools consisting of 231 different school buildings.

Table 3. The demographics of the participants in the initial sample of 1 198 subjects and in the subsample of 538 subjects (Study II).

Variable*		**Initial sample**	**Subsample**
Sex, n_t (%)	Female	950 (81)	443 (85)
	Male	222 (19)	81 (15)
Age, mean (min–max)		44 (24–65)	42 (25–65)
City, n_t (%)	Southern	590	
	Central	255	
	Northern	350	
Professional subgroups, n_t (%)	Class teachers	541 (45)	234 (43)
	Subject teachers	431 (36)	197 (37)
	Special education teachers	226 (19)	107 (20)
Smoking, n_t (%)	Current smoking	43 (4)	23 (4)
	Never smoked or ex-smoker	1 148 (96)	513 (96)
Asthma, n_t (%)	No	981 (86)	438 (86)
	Yes	155 (14)	69 (14)
Allergic rhinitis, n_t (%)	No	846 (75)	369 (73)
	Yes	288 (25)	139 (27)
Pollen allergy, n_t (%)	No	769 (70)	344 (67)
	Yes	380 (33)	171 (33)
Atopic eczema, n_t (%)	No	515 (90)	538 (100)
	Yes	58 (10)	0 (0)
Reflux disease, n_t (%)	No	1 009 (91)	454 (91)
	Yes	105 (9)	46 (9)
Thyroid disease, n_t (%)	No	1 036 (92)	462 (91)
	Yes	88 (8)	43 (9)
Vocal cord dysfunction (VCD), n_t (%)	No	1 115 (100)	501 (100)
	Yes	2 (0)	1 (0)
Asthma medication, n_t (%)	No	1 067 (89)	479 (89)
	Yes	131 (11)	59 (11)
Use of medication, n_t (%)	No	690 (58)	324 (60)
	Yes	495 (42)	212 (40)
Number of days absent due to sickness, median (Q_1–Q_3)		4 (2–10)	5 (2–10)
Sick leave > 14 days, n_t (%)	No	1 001 (84)	434 (81)
	Yes	191 (16)	99 (19)

* Some variables have missing values. Abbreviations: n_t: number of teachers; Q_1: lower quartile; Q_3: upper quartile.

In contrast to Studies I, III, and IV (n_t = 1 198), Study II was based on a subsample of 538 teachers from the southern city. The city was chosen, because there was more up-to-date information on the buildings in this city compared to the other cities, and also because a technical assessment of the condition of school buildings was available for every school building. Overall, the Real Estate Centers of the other cities could only provide limited information on the condition of their buildings with a relatively high amount of missing data. Fifty-two subjects were excluded, because they were working in two or more buildings, or their specific building, where they worked, was not identified. The teachers worked in a total of 67 school buildings at 39 schools. The dataset from the school buildings is reported in Vertanen-Greis et al. (2021c). To compare, there were approximately 65 school buildings comprising 40 schools in the central city, and in the northern city, there were more than 100 school buildings comprising of 48 schools, and both did not have enough detailed data available. Both samples were utilized in Study IV, and this was because the findings in Study III needed further studies, as the findings indicated that voice disorders, stress, and poor IEQ may act as a tangle, which associates with work ability. The study was then conducted as accurately as possible utilizing maximum sample size and the external assessment of IEQ, which is more reliable than self-assessment.

Voice disorders were assessed by means of a screening questionnaire. Accurate measurements of voice were not involved, because of the fact that the initial aim was to screen the situation in Finland. Indoor environment assessments were conducted with perceived (Studies I–IV) and technical (Studies II and IV) evaluations. The stress at work and Work Ability Score were measured with validated single-item questions. The questionnaires are included in Appendix A. The outcome variables were voice disorders (Studies I and II) and work ability (Studies III and IV), and the predictors were *voice disorders*, *stress at work*, and the *IEQ*, all of which have been highlighted in recent studies (Lin et al., 2020; Lyberg Åhlander et al., 2011; Medeiros & Vieira, 2019; Thorsen et al., 2019; Wargocki et al., 2020). The summary of the study aims, samples, and methods is presented in Table 4.

Table 4. A summary of the study aims, samples, and methods.

Sub-study	Aims	Sample, n_t	Methods
Study I	To evaluate (1) the prevalence of voice disorders and (2) the associated variables of voice disorders (sex, stress, and health symptoms)	1 198	Questionnaire (voice screening, stress at work, background variables)
Study II	To evaluate (1) the association between voice disorders and perceived indoor air quality, (2) voice disorders and technically assessed condition of school buildings, and (3) whether there was an agreement between the perceived indoor environmental quality and technical assessment of school buildings	538	Questionnaire (voice screening, stress at work, perceived indoor air quality background variables), technically assessed condition of school buildings
Study III	To investigate the interaction between voice disorders, stress at work, and perceived indoor environmental quality for self-reported work ability	1 198	Questionnaire (voice screening, stress at work, perceived indoor environmental quality, Work Ability Score, absence due to sickness, background variables)
Study IV	(1) To determine the association between stress at work and voice disorders—as a combined variable—and work ability, and (2) to study the association between the combined variable and the condition of school buildings	1 198 and 538	Questionnaire (voice screening, stress at work, Work Ability Score, background variables). Technical assessment was utilized for those involved the subsample (n_t = 538).

Abbreviations: n_t: number of teachers.

4.2 Study Methods

4.2.1 Methods to Assess Voice Disorders

For the present study, the voice questionnaire was to be concise, as the data were also collected for stress, IEQ, and work ability. In addition, an extensive survey may have reduced the motivation to participate (Fan & Yan, 2010). As a result, the screening questionnaire was chosen to study voice disorders. The screening questionnaire was originally developed to find potential risk groups (Simberg et al., 2001). It is used in multiple voice studies, mostly among teachers and student teachers (Table 2), and it is also routinely used at the Student Health Service Center in Turku (Simberg & Sala, 2008). In previous studies, some variations in vocal symptoms are used. In this thesis, however, a mixed sample of seven different vocal

symptoms was utilized to include as wide range of symptoms as possible in the questionnaire. The symptoms were *morning hoarseness*, *voice becomes strained or tires*, *voice becomes low or hoarse*, *voice breaks*, *difficulty in being heard*, *throat clearing or coughing*, and *pain around larynx*. This is the most used combination of symptoms except the *morning hoarseness*, as also shown in Table 2. The *morning hoarseness* was included in the questionnaire, because *stress at work* was of interest, and morning hoarseness is a symptom of reflux disease (Sala et al., 2001), which is, in turn, a stress-related symptom (Holmqvist et al., 2013). The response alternatives were "every day," "every week," "less often," and "never." Teachers who reported two or more of the six voice symptoms occurring weekly or more often in the previous 12 months were considered to have voice disorders. Once the questionnaire was developed, the subjects were also assessed with a laryngological evaluation. As concluded, those with two or more voice symptoms occurring weekly or more often had changes in their vocal folds (Sala et al., 2001). For analysis purposes, *hoarseness* was defined from the symptoms *morning hoarseness* and *voice becomes low or hoarse*. Recently, the voice symptoms are separated in different questions, and the questionaire is currently under validation, namely Screen11 (Zenger, 2019).

4.2.2 Methods to Assess Stress at Work

Stress at work was measured with a single-item question focusing on the experience of stress (Elo et al., 2003). The question was originally validated in different working groups in Finland and the Nordic countries, and it was suggested to identify well-being at work possibly better than health instruments based on illness. It is widely used in Finland as a part of the MM 040 questionnaire (Andersson, 1998) and is used in other countries (Besser et al., 2020; Hämmig, 2017). The question was "Stress means a situation in which a person feels tense, restless, nervous or anxious or is unable to sleep at night because his/her mind is troubled all the time. Do you feel this kind of work-related stress?" It was recorded on a 5-point Likert scale as "not at all," "little," "somewhat," "rather," and "very much." The *stress at work* was then classified into two or three classes, depending on the sample size, as a large sample size allowed for more classes as well as facilitating analytical purposes. In Studies I and III with the larger sample (n_t = 1 198), the variable was dealt with as three categories, where "very much" and "rather" were combined into one category as were the "little" and "not at all" answers. For the analysis in Study II, with the smaller sample size (n_t = 538), the variable was dealt with as two categories, where subjects with "rather" and "very much" were assigned as having stress.

In Study IV, the *stress at work* was also dichotomized, although the larger sample was used. This was because the information regarding voice disorders and stress at work was combined and categorized as follows: *group A* (no stress, no voice

disorders), *group B* (stress, no voice disorders), *group* C (no stress, voice disorders), and *group D* (stress, voice disorders). The resulting variable is referred to as the *combined stress and voice*.

4.2.3 Methods to Assess Indoor Environmental Quality

In the present thesis, the association between voice disorders and the indoor environmental quality was of interest. From this point of view, the focus was placed on the indoor environmental circumstances in school buildings that are closely linked to voice problems (Vilkman, 2004). The IEQ was measured utilizing both a technical and perceived evaluation. The PIEQ (Perceived Indoor Environmental Quality) was evaluated in Study III (n_t = 1 198), whereas a part of it, PIAQ (Perceived Indoor Air Quality), was assessed in Study II (n_t = 538). In addition to the technical evaluation, the agreement between these two assessments was studied. The technical evaluation was also utilized in Study IV.

The PIEQ assessment was based on the MM 040 questionnaire (Andersson, 1998), which has been validated by school staff (Tähtinen et al., 2020) and widely used with a different combination of questions (Hellgren et al., 2008; Reijula & Sundman-Digert, 2004; Savilahti et al., 2005). The combination of the questions utilized in Study III is widely used in schools and other workplaces in Finland (Tähtinen et al., 2020). Apart from the common definition of the IEQ being *indoor air quality*, *thermal*, *acoustic*, and *lighting conditions*, the *lighting conditions* and *tobacco smoke* were excluded, because light conditions are unrelated to voice problems and in Finland, smoking is forbidden in the schools and on the school grounds (Tobacco Act, 2016), and the prevalence of smoking is low in Finnish teachers in general (Putus et al., 2019). The questionnaire included complaints raised over the last three months regarding *draught, temperature too high, varying room temperature, temperature too low*, *stuffy "bad" air, dry air, insufficient ventilation, smell of mold or an earthen cellar, other unpleasant odors, dust or dirt*, and *noise* in the indoor environment. The options were *weekly*, *sometimes*, and *no, never*, and the last two were combined for the analysis. For analysis purposes, a sum variable was built and named the *PIEQ index*. A sum variable, also called a composite variable, means that it is created of two or more variables or measures that are highly related to each other conceptually or statistically (Ley, 1972). For this index, the cut-off point was optimized based on those observations reporting that 3 out of the 11 complaints had the greatest effect on work ability. Teachers, who reported two or less PIEQ complaints, were considered to have a negative *PIEQ index*, which indicates a good PIEQ, and those who reported at least three complaints were considered to have a positive *PIEQ index*, which indicates a poor PIEQ. All the complaints had the same weight in the index, because no theory appears to exist that

supports a certain stronger association between a single complaint in relation to work ability or voice disorders.

To validate the questionnaire data in Study II according to the recommendations (Haverinen-Shaughnessy et al., 2012), the PIAQ was compared to a technical assessment in 67 school buildings. The assessment was an overall evaluation of the deficiencies that are likely to decrease IAQ in school buildings and are closely linked to voice problems: challenges with ventilation and impurities (ASHRAE, 2010; Bayer et al., 2000; Corgnati & da Silva, 2011; Vilkman, 2004). The complaints concerned *stuffy "bad" air, dry air, insufficient ventilation, smell of mold or an earthen cellar, other unpleasant odors, dust or dirt*. The thermal conditions (ICQ) were not included, as the technical assessment focused on the condition of the school buildings. The temperature complaints were also found to be less evident in school staff, except for the *smell of mold or an earthen cellar* that had the lowest prevalence but which is one of the PIAQ complaints and thus included the perceived assessment (Tähtinen et al., 2020). 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 PIAQ nor were the teachers aware of the classification. The two experts were interviewed at the same time by the researcher because of limited resources. The data obtained provided an estimate of the deficiencies in the indoor air (IA) conditions in schools. 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 ventilation and impurities. The experts classified the school buildings into four categories: (1) *IA non-problems*, (2) *IA problems, not renovated*, (3) *IA problems, partially renovated*, and (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 Finnish benchmarking data from the National Institute for Health and Welfare (THL, n.d.) to evaluate health promotion activities in schools. The resulting variable is referred to as the *technical assessment*.

The assessment 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), additional data were used to make the final decision following the order of precedence being (a) *additional information on buildings given by the experts* available from 35 buildings and related to problems, renovations, and previous complaints; (b) *inspection reports of the City's Real Estate Center* based on walk-through risk assessment available for 41 buildings for the 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 assessment is described in detail in the dataset of the school buildings (Vertanen-Greis et al., 2021c).

In Study IV, the technical assessment was utilized to study the association between the condition of school buildings, and the combined voice disorders and stress. A disadvantage was that the technical assessment was only available for the subsample. The school buildings were constructed between 1904 and 2016, and 32 of the buildings had been thoroughly renovated at least once. Thirty-five percent of the buildings were constructed before 1970, 35% between 1970 and 1989, and 30% were constructed in 1990 or later. Renovations were mostly carried out in the buildings constructed between 1970–1989. According to the experts, there were centralized mechanical supply and exhaust ventilation systems in most of the buildings, and as is usual in Finland, these were mainly switched off during the night and on weekends except for 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 1 000 per building (n_b = 54; mean 289). The number of pupils per class was not assessed because the teachers tended to have several groups of different sizes each day depending 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.

4.2.4 Methods to Assess Work Ability

In Study III, work ability was assessed by using the *Work Ability Score* (WAS), which is based on a validated single-item question concerning the current work ability compared with the lifetime best (Tuomi et al., 1997). It also refers to other work-related aspects, such as job demands and mental resources (Ahlstrom et al., 2010; Ilmarinen, 2009; Tuomi et al., 1997). The WAS is widely used in Finland (Jääskelainen et al., 2016) and in other countries (Oakman et al., 2018). The question is recorded on a scale from 0 (“completely unable to work”) to 10 (“work ability at its best”) (Ahlstrom et al., 2010). WAS is a part of the Work Ability Index, which has the highest discriminating power over the entire index. In the analysis, the classification of WAS was used, which has been found to correspond best with that of the Work Ability Index (Ahlstrom et al., 2010) with ratings as, poor (0–5 points), moderate (6–7), good (8–9), and excellent (10). In the analyses, good and excellent work abilities were combined, and three categories were used. To compare the results with other studies, the distribution was reported in two ways. In view of the fact that the distribution was skewed, the median with quartiles was used. However, because of the large sample size and the values only being between 0–10, the mean

is almost the same as the median and, thus, can also be reported. A background variable close to work ability, absence due to sickness, was assessed utilizing two variables, the *number of days absent due to sickness* during the previous year and *sick leave over 14 days*.

4.3 Background Variables

The background variables being *sex*; *age*; *city*; and *professional subgroups*, which were being class teacher, a subject teacher, or a special education teacher; were assessed. The *subjects taught* were grouped into four groups, and each group included subjects that were related to each other, for example, in terms of objectives. The four groups were *languages* including 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, and crafts. *Smoking* was handled as a categorical variable (never smoked or ex-smoker–current smoker). Voice-related disease variables were investigated by asking "Has your doctor stated that you have *asthma* / *allergic rhinitis* / *pollen allergy* / *atopic eczema* / *reflux disease* / *thyroid disease* / *vocal cord dysfunction (VCD)* / *medication used*?" A question was asked about the *number of years a teacher had been working in the present building* as well as whether *the voice gets worse in the workplace*, and the variable was assessed with two categories being “No” (no–I cannot say) and “Yes” (yes, almost immediately–yes, within half an hour–yes, within a few hours).

Because all the participants were full-time workers, meaning at least 16 hours teaching per week (*KVTES*, n.d.), v*ocal load* was assessed by asking about the *use of the voice during leisure time* by using a numerical rating scale from 0 to 10, and the occurrence of *voice-demanding hobbies*; *coaching*; *participating in sport*; singing in a *choir*; or *other kinds of singing, for example, solo singing* (Ohlsson et al., 2012). In addition, the *number of working years* was investigated because previous studies have shown contradictory results regarding the association between years of teaching and voice problems (de Medeiros et al., 2008; Ilomaki et al., 2009; Roy et al., 2004a; E. Smith et al., 1997). As a part of *vocal load* assessments, the PIEQ complaint *noise* was used in Study I.

4.4 Ethical Aspects

Ethical approval was given by the Ethics Committee of the University of Turku (26/2016). A request for permission to conduct the study was also sent to and endorsed by the Education departments of the cities in which it was performed, and

the principals were asked to encourage teacher participation. The questionnaire was sent directly to the work email address of the participants. They gave a written informed consent to the inclusion of material pertaining to themselves; they acknowledged that they cannot be identified via the paper and that they were pseudonymized. The questionnaire was designed with a limited number of questions to motivate teachers to participate. The data were analyzed only at a group level, and the schools and the cities were unnamed.

4.5 Statistical Analyses

Statistical analysis with a chi-square test or a Fisher's exact test were performed to study the association between the two categorical variables in all studies. The *age* was normally distributed, and it was thus tested with one-way analysis of variance (ANOVA). The variables from WAS, the *number of days absent due to sickness*, and the *number of working years* were tested with the Kruskal Wallis test (Study III) and the Wilcoxon rank sum test (Study IV), because these variables were skewed.

A logistic regression analysis model was created for a deeper investigation of voice disorders, including at least *sex*, *city*, *professional subgroups, working years*, *stress at work*, *use of voice during leisure time*, and *smoking* status in Study I, and *asthma*, *allergic rhinitis*, *asthma medication* were evaluated by adding one of these at a time due to the collinearity of these variables. For all these explanatory variables, the adjusted odds ratio (aOR) and their 95% confidence intervals (CI) were calculated. In Study III, a logistic regression model was also used to study associations between the WAS and *voice disorders*, *stress at work*, *PIEQ index*, *use of medication*, *sex*, and *age*. In addition, an adjusted odds ratio (aOR) for these variables was calculated and adjusted with *sex* and *age*. A logistic regression analysis model for ordinal data was created for the results of Study IV, adjusted with *sex*, *age*, *asthma*, *reflux*, and *sick leave over 14 days*. In Study II, a log-binomial regression model (McNutt et al., 2003) was utilized to study associations between voice disorders and *technical assessment*, *sex*, *stress*, or *asthma*. In addition, unadjusted (uRR) and adjusted relative risk (aRR) for these variables 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. The analyses were performed using a JMP 14.2.0 Pro and 15.1.0 Pro for MacOS or an SAS® System, version 9.4 for Windows (SAS Institute Inc., Cary, NC, USA).

5 Results

5.1 Voice Disorders and the Background Variables (Study I)

Assessed with 1 198 primary and secondary school teachers in Finland, the prevalence of voice disorders was 54% (95% CI 51%–57%) over a 12-month period. The most common voice symptoms were *voice tires easily* (50%; 95% CI 47%–53%), *hoarseness* (49%; 95% CI 47%–52%), and *throat clearing or coughing* (46%; 95% CI 43%–49%) (Table 5). The female participants suffered more from voice disorders than the males, and all the six voice symptoms occurred substantially more often in the female participants than in the males. The mean age was equal for teachers with or without voice disorders.

Table 5. Prevalence of all six voice symptoms in teachers by sex (n_t = 1 195).

Symptom	Total, n_t (%)*	Females, n_t (%)	Males, n_t (%)	p value
Voice tires easily	596 (50)	498 (53)	87 (40)	0.0005
Hoarseness	591 (49)	491 (52)	92 (42)	0.0094
Voice breaks	325 (27)	281 (30)	36 (16)	< 0.0001
Difficulty in being heard	248 (21	216 (23)	27 (12)	0.0005
Pain around larynx	337 (28)	294 (31)	36 (16)	< 0.0001
Throat clearing or coughing	549 (46)	463 (49)	73 (33)	< 0.0001

* Some variables have a few missing values. Abbreviations: n_t: number of teachers. P values were calculated with a chi-square test. Published in Study I (Vertanen-Greis et al., 2020a).

Sex, *asthma*, *allergic rhinitis*, and *asthma medication* were all substantially associated with voice disorders. The most used medicine groups were antihistamines, corticosteroids, bronchodilators, and nasal medication. The use of all these medicine groups associated with voice disorders (all p values < 0.0001). The subjects with allergic rhinitis used most likely antihistamines and nasal medication, whereas those with asthma did not (p values < 0.0001). Four percent of the

participants were current smokers, and the association between voice disorders and smoking was insignificant. Altogether, 58% of the teachers reported that their voice got worse in the workplace, and this was also more likely for those with voice disorders ($p < 0.0001$). There were no differences between voice disorders and the *professional subgroups* ($p = 0.28$) or the *subjects taught* ($p = 0.50$). *Use of voice during leisure time* associated with voice disorders ($p = 0.036$). The association between voice disorders and background variables are illustrated in detail in Table 6. The subjects who suffered either *hoarseness* or *morning hoarseness*, which are the two *hoarseness* symptoms, had more often *reflux* (p values < 0.001). Voice disorders were more prevalent in the subjects with thyroid disease than in those without ($p = 0.0059$).

Table 6. The association between voice disorders and background variables (n_t = 1 198).

Variable		Total*	Without voice disorders	With voice disorders	p value
Sex, n_t (%)	Female	949	414 (44)	535 (56)	0.0004
	Male	220	125 (57)	95 (43)	
Age, mean (min–max)		1 182	44 (24–64)	44 (25–65)	0.27
Asthma, n_t (%)	No	979	483 (49)	496 (51)	< 0.0001
	Yes	154	42 (27)	112 (73)	
Asthma medication, n_t (%)	No	1 065	526 (49)	539 (51)	< 0.0001
	Yes	130	27 (21)	103 (79)	
Allergic rhinitis, n_t (%)	No	843	429 (51)	414 (49)	< 0.0001
	Yes	288	99 (34)	189 (66)	
Reflux disease, n_t (%)	No	1 006	488 (49)	518 (51)	0.0004
	Yes	105	32 (30)	73 (70)	

* Some variables have a few missing values. Abbreviations: n_t: number of teachers. P values were calculated with chi-square, Fisher's exact tests, and one-way ANOVA. Table 6 is modified from Study I (Vertanen-Greis et al., 2020a).

5.2 Voice Disorders Associating with Stress at Work (Study I)

Assessed with the sample of 1 198 teachers, "rather" or "very much" *stress at work* was reported by 25% of teachers, whereas 36% of subjects felt somewhat stressed and 39% reported little stress or no stress. Stress had an overall significant association with voice disorders, as the more stress had more voice disorders, and the less stress had less voice disorders ($p < 0.0001$). The occurrence of each voice symptom was also associated with stress (all p values < 0.0001). When evaluated with logistic regression, *stress at work* had the strongest association with voice disorders (Table 7).

Table 7. The association between voice disorders and possible associated variables ($n_t = 1\ 198$).

	Variable	Wald Chi-Square (df)	OR (95% CI)
Variables in all models	Stress at work	65.3 (4)***	3.6 (1.7–7.4)
	Female sex	6.63 (1)**	1.5 (1.1–2.1)
	Smoking	0.61 (1)	1.3 (0.68–2.5)
Variables in separate models	Asthma	23.1 (1)***	2.7 (1.8–4.0)
	Allergic rhinitis	20.2 (1)***	2.0 (1.5–2.7)
	Asthma medication	28.8 (1)***	3.5 (2.2–5.6)

Abbreviations: CI: confidence intervals; df: degrees of freedom; OR: odds ratio. Test statistics (Wald Chi-Square) and its degrees of freedom (df) are presented with OR (95% CI). Significant p values are indicated as follows; ** = $p < 0.001$; *** = $p < 0.0001$. Published in Study I (Vertanen-Greis et al., 2020a).

Females suffered more stress than males ($p = 0.0005$). The subjects with stress were slightly younger than those without stress ($p = 0.023$). The subjects with stress had more *reflux disease* than those without stress ($p = 0.0056$). There was no association between stress and the *professional subgroups*.

5.3 Voice Disorders Associating with the Indoor Environmental Quality (Study II)

The PIEQ was assessed with the initial sample, whereas a part of it, the PIAQ, was evaluated with the subsample together with the *technical assessment*. In addition, the agreement between technical and perceived assessments was determined. In Study II ($n_t = 538$), the prevalence of voice disorders was 56% (95% CI 51%–60%) being consistent with the initial sample. The females suffered more from voice disorders

than the males (p = 0.034), and the mean *age* was similar between those teachers with and without voice disorders, as it was in the initial sample.

Of the PIEQ complaints, *stuffy "bad" air, insufficient ventilation, dust or dirt*, and *noise* were reported most frequently (42%–49%). *Temperature too high, varying room temperature, temperature too low*, and *smell of mold or an earthen cellar* were reported by a maximum of 13%.

In Study III, the *PIEQ index* was negative in 554 (52%) subjects and positive in 520 (48%) subjects. As Figure 2 shows, *stuffy "bad" air, insufficient ventilation, dust or dirt*, and *noise* were reported mostly. Teachers with voice disorders reported more complaints of PIEQ than those without voice disorders.

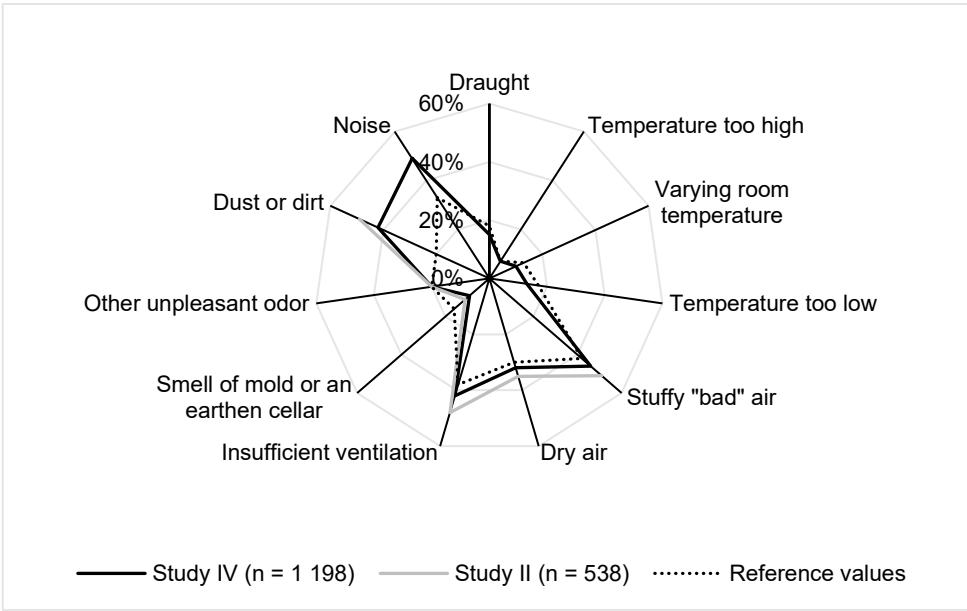

Figure 2. Perceived indoor air quality in Study II (n_t = 538) and perceived indoor environmental quality in Study III (n_t = 1 198) compared to reference values in Tähtinen et al. (n = 5 241) (Tähtinen et al., 2020). Associations between voice disorders and each complaint were significant in both samples (all p values < 0.0001). Figure 2 is modified from Study II (Vertanen-Greis et al., 2021a).

Voice disorders associated significantly with the *PIEQ index*. Those without voice disorders were more often found to have a negative *PIEQ index* indicating a good PIEQ, whereas the ones with voice disorders were more often found to have a positive index indicating a poor PIEQ. Further, voice disorders associated with each PIEQ complaint most clearly, and the positive *PIEQ index* associated with all voice symptoms (all p values < 0.0001).

Females reported significantly more all of the PIEQ complaints except for *smell of mold or an earthen cellar* and *insufficient ventilation*. *Age* was not associated with PIEQ with the exception that those who reported *stuffy "bad" air* or *insufficient ventilation* were slightly younger on average than those who did not report the complaint (both 45 versus 43 years, p values < 0.001). The special education teachers reported less *dust or dirt* (p = 0.0066) and *noise* (p = 0.015) but more *draught* (p = 0.0403) and *temperature too low* (p = 0.0003) compared to their colleagues. The teachers of artistic and practical subjects reported more *noise* (p = 0.0002) and *dust* (p = 0.024).

In Study II, the *technical assessment* showed that 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 indoor air problems. Table 8 shows the statistically significant association between the *technical assessment* and voice disorders. Voice disorders were more prevalent among the teachers employed in the buildings with indoor air problems than in the buildings without problems, but less often than in the buildings where the problems were corrected. Furthermore, voice disorders were more prevalent in the buildings that were constructed in 1970 or later than in the older buildings. In addition, the older buildings had more *IA problems* (p < 0.0001). Voice disorders were not associated with the *number of pupils per building*, however, the buildings with fewer than 200 pupils had the least *IA problems*. *Asthma* did not associate with the *technical assessment*.

Table 8. Associations between voice disorders and the technical assessment (n_t = 538).

Variable*		Total	Without voice disorders	With voice disorders	p value
Technical assessment, n_t (%)	IA non-problems	95	53 (56)	42 (44)	0.010
	IA problems	366	160 (44)	206 (56)	
	IA problems renovated	76	25 (33)	51 (67)	

* Some variables have a few missing values. Abbreviations: IA: indoor air; n_t: number of teachers. P values were calculated with chi-square test. Table 8 is modified from Study II (Vertanen-Greis et al., 2021a).

To study the association between voice disorders and *technical assessment* in more depth, a model including background variables was created (Table 9). After adjustment for *sex*, *stress*, and *asthma*, the prevalence of voice disorders was 47% higher in subjects working in renovated buildings and 28% higher in those working

in buildings with indoor air problems compared to teachers working in the non-problem buildings indicating a possible association between *technical assessment* and voice disorders. The inclusion of the covariates had no significant effect on the unadjusted relative risk (uRR). When studying the association between voice disorders and each PIAQ complaint within the same model, all complaints were significantly associated with voice disorders.

Table 9. Unadjusted and adjusted relative risk between voice disorders and technical assessment (n_t = 538).

Variable	uRR (95% CI)	p value	aRR (95% CI)	p value
IA problems vs. IA non-problems	1.27 (1.00–1.62)	0.052	1.28 (0.99–1.64)	0.059
IA problems renovated vs. IA non-problems	1.52 (1.15–2.00)	0.0030	1.47 (1.11–1.95)	0.0071
IA problems vs. IA problems renovated	0.84 (0.70–1.00)	0.058	0.87 (0.72–1.04)	0.13
Sex		-	1.24 (0.97–1.60)	0.092
Asthma		-	1.31 (1.08–1.59)	0.0070
Stress		-	1.27 (1.08–1.48)	0.0033

Abbreviations: aRR: adjusted relative risk; CI: confidence intervals; IA: indoor air; uRR: unadjusted relative risk; vs.: versus. P values were calculated with a log-binomial regression model. Published in Study II (Vertanen-Greis et al., 2021a).

The technical assessment associated significantly with the results of the PIAQ (all p values < 0.05). The employees in the non-problem buildings made fewer complaints than those in the renovated buildings, while the employees in the problem buildings made the most complaints.

5.4 Work Ability Associating with Voice Disorders, Stress at Work, and the Indoor Environmental Quality (Study III)

The results in Study III revealed that the WAS median was 8 (Q_1: 7, Q_3: 9). Of the subjects, 71% (95% CI 69%–74%) had good work ability (WAS 8–10). Moderate work ability (WAS 6–7) was reported by 23% (95% CI 20%–25%) of the subjects, and 6% (95% CI 5%–8%) had poor work ability (WAS 0–5).

WAS was found to be significantly associated with *voice disorders*, *stress at work*, and the *PIEQ index* (all p values < 0.0001). Of the teachers without voice disorders, 85% reported a WAS of 8–10, and 2% reported a WAS of 0–5, whereas those with voice disorders reported 60% and 10%, respectively. Regarding *stress at*

work, 87% reported "not at all" or "little", i.e., a WAS between 8–10, and 2% reported a WAS between 0–5, compared to those with "rather" or "very much" stress at 45% versus 16%. Eighty-five percent of the teachers, who reported a negative *PIEQ index* indicating a good PIEQ, had a WAS between 8–10, and 1% had a WAS between 0–5, while those with a positive *PIEQ index* reported 60% and 10%, respectively.

The occurrence of each voice symptom was clearly associated with the lower WAS (p values < 0.0001). Each PIEQ complaint associated with a lower WAS with a p value of < 0.05 except *temperature too low*. It should also be mentioned that the positive *PIEQ index* associated with stress (p < 0.0001).

As Table 10 shows, female teachers had a lower WAS than male teachers, while the mean *number of working years* did not associate with the WAS. The use of respiratory medicines (e.g., antihistamines, corticosteroids, bronchodilators, nasal medication) associated significantly with the lower WAS (p < 0.0001).

Table 10. Association between Work Ability Score categories and the background variables (n_t = 1 198).

Variable		Total*	WAS 0–5	WAS 6–7	WAS 8–10	p value
Sex, n_t (%)	Female	941	64 (7)	210 (22)	667 (71)	0.034
	Male	222	5 (2)	54 (24)	163 (74)	
Age, mean (min–max)		1 176	43 (27–61)	44 (25–63)	44 (24–65)	0.36
Asthma, n_t (%)	No	976	51 (5)	200 (21)	725 (74)	< 0.0001
	Yes	151	18 (12)	48 (32)	85 (56)	
Number of days absent due to sickness, median (Q_1–Q_3)		1 183	12 (5–26)	7 (3–15)	3 (1–7)	< 0.0001
Sick leaves > 14 days, n_t (%)	No	992	39 (4)	199 (20)	754 (76)	< 0.0001
	Yes	191	33 (17)	69 (36)	89 (47)	

* Some variables have a few missing values. Abbreviations: n_t: number of teachers; Q_1: lower quartile; Q_3: upper quartile; WAS: Work Ability Score. P values were calculated with a chi-square test and a Oneway Anova. Table 10 is modified from Study III (Vertanen-Greis et al., 2020b).

Table 11 illustrates a model for studying the association between work ability and three other variables including background variables adjusted for *sex* and *age*. As shown, *sex*, *age*, and *use of medication* were all clearly associated with WAS. Of these variables, stress had the strongest association with WAS.

Table 11. Adjusted odds ratio for voice disorders, stress, perceived indoor environmental quality (PIEQ) index, and the use of medication for decreasing work ability under 8 (n_t = 1 198).

Variable		aOR (95% CI)	p value
Voice disorders	Yes–No	2.44 (1.73–3.44)	< 0.0001
Stress	Rather or very much–Somewhat	2.88 (2.00–4.15)	< 0.0001
	Somewhat–Not at all or little	2.27 (1.53–3.37)	
	Rather or very much–Not at all or little	6.53 (4.31–9.90)	
PIEQ index	Positive–Negative	2.63 (1.86–3.71)	< 0.0001
Use of any medication	Yes–No	1.48 (1.07–2.03)	0.017

Abbreviations: aOR: adjusted odds ratio; CI: confidence intervals; PIEQ: perceived indoor environmental quality. Analyzed with the logistic regression model (adjusted for age and sex). Published in Study III (Vertanen-Greis et al., 2020b).

5.5 The Interaction between Stress at Work and Voice Disorders for Work Ability of Teachers (Study IV)

In Study IV, 39% of the subjects were in *group A* (no stress, no voice disorders), 36% in *group C* (no stress, voice disorders), 17% in *group D* (stress, voice disorders), and 7% in *group B* (stress, no voice disorders). WAS and the *combined stress and voice* associated significantly (all p values < 0.0001). Ninety percent of the subjects in *group A* reported good work ability, whereas 40% of those in *group D* reported poor work ability (Figure 3). The association between WAS and the *combined stress and voice* was also significant when studied using logistic regression models adjusted for *sex*, *age*, *asthma*, *reflux*, and *sick leave over 14 days* (p < 0.0001).

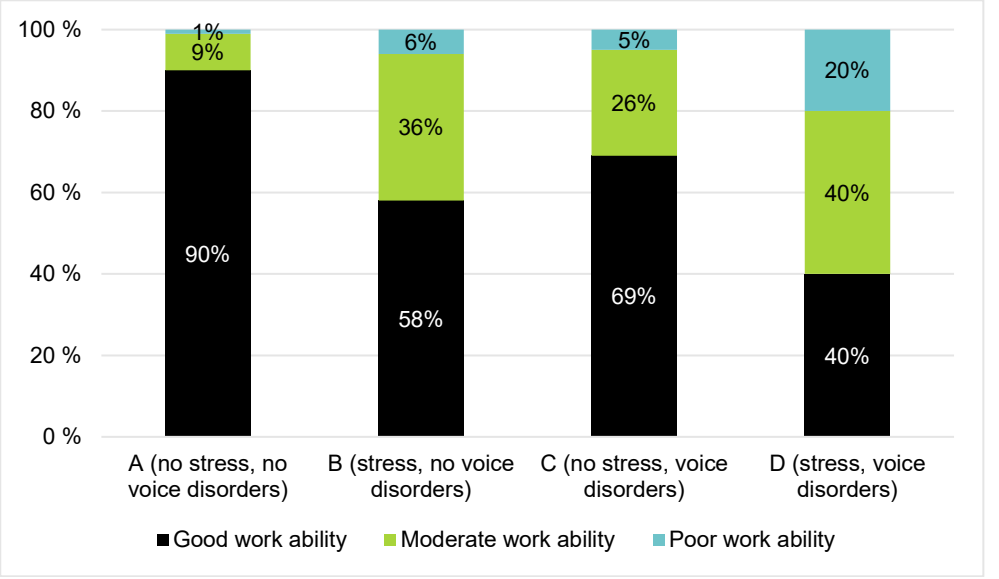

Figure 3. The association between the *combined stress and voice* categories and work ability (n_t = 1 198). Unpublished results in Study IV (Vertanen-Greis et al., n.d.-b).

As illustrated in Table 12, the *combined stress and voice* categories associated significantly with all the background variables except for the *professional category*. Most of the females were in *group A* and *C*, whereas most of the male teachers were only in *group A*. The participants in *group B* were younger than the other subjects. *Group A* was the largest group of subjects, who worked in the non-problem buildings. *Group C* was the largest group in the buildings with both *IA problems, not renovated* and *IA problems renovated*.

Table 12. The associations between the *combined stress and voice* categories in relation to background variables (n_t = 1 198) and technical assessment (n_t = 538). The samples are separated with a double line.

Variable		Total*	A (no stress, no voice disorders)	B (stress, no voice disorders)	C (no stress, voice disorders)	D (stress, voice disorders)	p value
Sex, n_t (%)	Female	947	341 (36)	73 (8)	352 (37)	181 (19)	0.0002
	Male	219	111 (51)	13 (6)	73 (33)	22 (10)	
Mean age, (min–max)		1 179	45 (24–64)	41 (25–59)	44 (25–65)	44 (25–62)	0.0056
Profession, n_t (%)	Class teachers	537	218 (41)	36 (7)	189 (35)	94 (17)	0.69
	Subject teachers	430	156 (36)	31 (7)	166 (39)	77 (18)	
	Special education teachers	225	91 (40)	20 (9)	80 (36)	34 (15)	
Number of days absent due to sickness, median (Q_1–Q_3)		1 186	3 (0–5)	6 (2–12)	5 (2–12)	6 (3–15)	< 0.0001
Sick leave > 14 days, n_t (%)	No	997	433 (44)	69 (7)	343 (34)	152 (15)	< 0.0001
	Yes	189	29 (15)	18 (10)	89 (47)	53 (28)	
Technical assessment, n_t (%)	IA non-problems		43 (45)	9 (10)	33 (35)	9 (10)	0.040
	IA problems**		126 (34)	34 (9)	138 (38)	68 (19)	
	IA problems renovated***		19 (25)	6 (8)	30 (39)	21 (28)	

* Some variables have a few missing values. ** IA problems, not renovated. *** IA problems renovated. Abbreviations: IA: indoor air; n_t: number of teachers; Q_1: lower quartile; Q_3: upper quartile. P values were calculated with a chi-square test, a Oneway Anova, and the Wilcoxon rank sum test. Unpublished results in Study IV (Vertanen-Greis et al., n.d.-b).

6 Discussion

In the present thesis, voice disorders were studied together with stress at work and the IEQ to assess their association with work ability. In this Finnish teachers' sample (n_t = 1 198), more than half (54%) suffered from voice disorders. Stress had the strongest association with voice disorders, and teachers with voice disorders reported significantly more complaints due to their indoor environmental conditions than those without voice disorders. The results also indicated a possible association between the technically assessed poor condition of school buildings and voice disorders. There was an agreement between perceived and technical assessments. Further, stress and voice disorders together had a stronger association with decreased work ability, than when they were evaluated separately. Overall, voice disorders, stress at work, and poor IEQ were associated with the decreased work ability in teachers.

6.1 Methodological Considerations

Voice symptoms are generally studied with a self-reporting questionnaire, and the questionnaires are also used as a part of clinical evaluations (Cantor Cutiva et al., 2013; Sataloff, 2017). This is not only for economical and timing reasons but also to document the experience of one's own voice. Whereas a clinical assessment would provide more specific information about the voice in addition to a questionnaire, the questionnaire is more practical when collecting epidemiological data. In the present study, a large sample size was utilized compared to voice studies in general (Cantor Cutiva et al., 2013). In studies focused on the health effects of poor IAQ, vocal symptoms are seldom mentioned, but when mentioned, they are typically defined only as hoarseness (Patovirta et al., 2004a; Patovirta et al., 2004b; *WHO*, 2009). It is a rather incomplete definition and does not represent the complexity of the situation as from a speaker's perspective. For example, vocal symptoms may be confused with symptoms caused by infections or respiratory diseases such as asthma (Patovirta et al., 2004a).

In the present thesis, the main variables were assessed by using compact questionnaires, because an extensive survey may have reduced the motivation to participate (Fan & Yan, 2010). A screening questionnaire was used to study voice

disorders, as it contained a limited number of items but is assessed as having a significant association with the VHI (Greve et al., 2019). The assessment was conducted by utilizing six out of the seven questions that were used in the present thesis, i.e., *morning hoarseness*, *voice gets strained or tired*, *voice gets low or hoarse*, *voice breaks*, *difficulty in being heard*, *throat clearing or coughing while talking*, *feel of pain, tension, or a lump in the throat*. The screening questionnaire was further supported with a limited recall period of 12 months, and a laryngological evaluation once the questionnaire was developed (Sala et al., 2001; Simberg et al., 2001). The questionnaire is not only used in Finland but also in Sweden (Ohlsson et al., 2015; Ohlsson et al., 2012) and in Norway (Greve et al., 2019). The questionnaire also refers to another main variable in the present thesis, the IEQ, as the symptom *difficulty in being heard* may indicate the occurrence of background noise. As a limitation, the questionnaire has been modified from study to study and by using different combinations with 6 to 8 voice symptoms. Additionally, two different symptoms were combined in three of the questions with *voice becomes strained or tired*, *voice becomes low or hoarse*, and *throat clearing or coughing*, and this creates challenges to knowing which symptom exactly was being measured. To avoid confusion and potential bias, this limitation is addressed in the recent version of the questionnaire. In the Screen11 questionnaire, each of the 11 voice symptoms are separated into different questions. The questionaire is currently under validation (Zenger, 2019).

Further, questionnaires of one question were used to study the *stress at work* and WAS. The instruments are validated and widely used. In general, the use of single-item measures is a strategy to shorten the survey, which may result in a higher response rate, especially when conducted with validated items (Fisher et al., 2016). WAS is a reliable instrument to assess work ability (Ahlstrom et al., 2010; Ilmarinen, 2009). It refers not only to current work ability compared with a lifetime best, but also other work-related aspects, such as job demands and mental resources (Ahlstrom et al., 2010; Ilmarinen, 2009; Tuomi et al., 1997). Both the WAS and the Work Ability Index are also utilized outside Finland (Guidetti et al., 2018; McGonagle et al., 2015). *Stress at work* was originally validated in different working groups in Finland and the Nordic countries identifying well-being at work possibly better than health instruments based on illness (Elo et al., 2003). The stress scale is a part of the MM 040 questionnaire (Andersson, 1998). The MM 040 questionnaire is not as brief as the others, as it includes 11 environmental aspects. However, it is commonly used in Finland to assess indoor air problems in work environments and has recently been validated for a school staff (Tähtinen et al., 2020).

To shorten the questionnaire, some questions were excluded. For example, a common method to assess vocal load is the group size. The average group size does not convey the whole truth about the working circumstances, as teaching can be

organized in many flexible ways depending on the subject taught and the provision of learning support. In previous studies, the results regarding the association between group size and voice problems have been contradictory (Cantor Cutiva et al., 2013; Gadepalli et al., 2019; Karjalainen et al., 2020; Moy et al., 2015), and a recent review (Byeon, 2019) showed an insignificant association between group size and voice disorders. Teachers with voice symptoms have even had a smaller group size than those without problems (Lyberg Åhlander et al., 2011). As also reported, the average group size is smaller in Finland than in the OECD countries in general with the mean group size in Finnish primary schools being 19.6 pupils per class, while the OECD average is 21.1 (2018). As a result, questions about the group size were not included in order to have the questionnaire as short as possible.

Previous research has noted that it is challenging to assess reliably the effects of indoor exposure on voice symptoms (Laukkanen et al., 2008; Lyberg Åhlander, Rydella, et al., 2015). In this thesis, the methodological decision was to study the association and not the effect, as this is not possible using a cross-sectional design assessing the relation between voice disorders and the condition of the school buildings and to validate the questionnaire data regarding the PIAQ assessment using a technical assessment according to the recommendations (Haverinen-Shaughnessy et al., 2012) (Study II). According to the results, the technical assessment was significantly associated with the PIAQ and this supported the validity of the self-reported data, as the teachers reported more complaints in the buildings with indoor air problems than in the other buildings. The technical assessment was based on the Finnish benchmarking system (THL, n.d.) focusing on the condition of the school buildings. Even though the assessment may be imprecise, it represents the overall picture of the conditions in school buildings in the city and the situation in Finland in general.

The technical assessment was performed more explicitly at the building level, whereas the Finnish benchmarking system provides only data from the school level (THL, n.d.). However, this assessment is based on an evaluation that is a subject for potential bias. For example, there may be differences in how the experts assess the level of a deficiency or what they determine as being an adequate renovation. Furthermore, deficiencies may also occur that are unknown in a building. While the experts evaluated the buildings to the best of their knowledge, the school buildings are large and various interactions among the variables exist in the buildings. Additionally, all the individuals that evaluate school buildings, whether they are teachers, principals, employees, building owners, occupational physicians, inspectors of the City's Environment Center, and those responsible for maintenance and renovation, will evaluate the buildings using different criteria. This is made obvious by the lack of unambiguous guidelines on whether a renovation has been done adequately. It thus becomes obvious that evaluations are challenging. (Bayer

et al., 2000; Corgnati & da Silva, 2011) The challenges have also been presented in other studies (Haverinen-Shaughnessy et al., 2012; Sauni et al., 2015) and exist in the inspection reports of the City's Environment Center and the benchmarking data of THL. The inspection reports are focused on health impacts, and there may be varying findings in the walk-through risk assessment regarding how extensively and carefully it has been carried out. The results of these inspections are then reported by the school principals every two years for the benchmarking data using a questionnaire. Instead of targeted data concerning the individual buildings in a school, the principals make a joint assessment of all the buildings belonging to their school. This is problematic for the benchmarking data, as out of the 22 schools, only 13 consisted of only one building, and therefore only the data from these buildings met the targeted criteria. In addition, both the inspection reports and the benchmarking data were from several years prior to the study and perhaps consequently have caused a slight limitation, as they may not reflect the current situation.

6.2 Voice Disorders in Teachers (Study I)

The results suggest that the prevalence of voice disorders in the12-month period was 54% in 1 198 Finnish teachers being consistent with the findings with the subsample in Study II (n_t = 538; 56%). The prevalence was consistent across the cities, which also means that no climatic effects on voice disorders were observed. The occurrence of voice disorders was in line with earlier questionnaire studies for teachers, where the prevelance in a 12-month period for 82 female teachers was 54% (Thomas et al., 2006). However, the prevalence was assessed with only one simple question being, "Did you experience voice complaints during the past year?" Investigated as a lifetime prevalence, previous studies showed the prevalence of voice disorders to be 51% in a sample of 994 teachers at different school levels (van Houtte et al., 2011), and also 51% when voice disorders were defined as voice problems (n = 504) (Angelillo et al., 2009). However, there are also contradictory findings (Cantor Cutiva et al., 2013), 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 15%–80% (Cantor Cutiva et al., 2013). As can be seen, a comparison between studies is complicated as the definitions vary. Not only the questionnaires but also the clinical evaluations have led to varied results (Sala et al., 2001; Sliwinska-Kowalska et al., 2006; Tavares & Martins, 2007). In Finland, the clinical findings have suggested that 29% of 262 teachers had abnormalities, while the prevalence of voice disorders using a questionnaire was 37% (Sala et al., 2001). In Poland (Sliwinska-Kowalska et al., 2006), the prevalence of voice disorders was 33% in 425 teachers. When vocal

symptoms were assessed with a questionnaire over the entire working lifetime, the prevalence was 69%. In Brazil (Tavares & Martins, 2007), abnormal findings occurred in 46 out of 80 teachers, and the sample consisted of 40 teachers with vocal symptoms and 40 teachers without vocal symptoms.

Findings with the screening questionnaire suggested that the prevalence of voice disorders in teachers had increased considerably from 5% (Pekkarinen et al., 1992) to 20% (Simberg et al., 2005). The present findings of a 54% prevalence of voice disorders in teachers indicated a continuing increase. In the screening questionnaire, the frequency of symptoms was meant to indicate the severity of voice disorders (Simberg et al., 2001). In the present study, the most common voice symptoms were *voice tires easily* (50%; 95% CI 47%–53%), *hoarseness* (49%; 95% CI 47%–52%), and *throat clearing or coughing* (46%; 95% CI 43%–49%). To compare the results with those provided by other studies with the same questionnaire, the frequencies in Study I were slightly higher depending on the sample with *voice tires easily* 8–54%, *hoarseness* (*voice becomes low or hoarse*) 6–43%, and *throat clearing or coughing* 20–41% (Greve et al., 2019; Hagelberg & Simberg, 2015; Rantala et al., 2012; Simberg et al., 2000, 2001, 2005, 2009).

Overall, the prevalence of voice disorders in the present thesis is in line with earlier findings and is supported by a limited recall period, as recommended (Sala et al., 2001). Once the questionnaire was developed, the subjects were also assessed with a laryngological evaluation. As concluded, those with two or more voice symptoms occurring weekly or more often had changes to their vocal folds (Sala et al., 2001). Thus, although a questionnaire without a clinical assessment was used in this study, the prevalence of voice disorders is reliable.

6.2.1 Voice Disorders in Relation to Background Variables

The extensive vocal load is an obvious risk for voice disorders in teachers (Cantor Cutiva et al., 2013; Martins et al., 2014; Vilkman, 2004). However, it is challenging to reliably assess the effect of a vocal load on the voice (Laukkanen et al., 2008; Lyberg Åhlander, Rydella, et al., 2015). In this thesis, vocal load at work was assessed using *noise*, and this was also handled as a complaint about the IEQ; the *number of working years*; and the duration of voice use, which was standardized by involving only full-time teachers in the study. The group size was not assessed, as the teachers tended to have several groups of different sizes each day, depending, for example, on the subject and the need for learning support.

The results of sex differences were in line with earlier studies. Female teachers have reported significantly more voice symptoms in studies during different decades, countries, designs, and sample sizes (n = 522–73 146) (Lyberg Åhlander et al., 2019; Nerrière et al., 2009; Simberg et al., 2009b; E. Smith et al., 1998; Trinite, 2016). The

sex-related differences are mainly caused by physiological reasons, such as the smaller size of the larynx in females. The anterior angle of the thyroid cartilage is larger in females than in males and leads to the posterior cartilaginous part of the glottis to remain open during voicing. Therefore, the strain caused by the collision of vocal folds hits a smaller area. (Dejonckere, 2001a; Titze, 1989) Women have shorter vocal folds and produce a voice at a higher fundamental frequency, and the number of vibrations is 50% lower in males than in females (Roy et al., 2004a; Vilkman, 2004). In addition, females speak with a louder voice compared to males, and female teachers tend to speak even higher after workdays (Bottalico & Astolfi, 2012; Laukkanen et al., 2008). In Study I, the self-reported asthma was clearly associated with voice disorders, and the association between asthma medication and voice disorders was even stronger than the association between asthma and voice disorders. This is consistent with the earlier conclusions (*Asthma: Current Care Guidelines*, 2012). As previously reported by Roy et al., (2004b), the prevalence of voice disorders was higher for those with asthma or respiratory allergies ($p < 0.0001$). Further, subjects with an allergy had more vocal symptoms than those without an allergy (39% versus 11%), and 37% of the allergic subjects reported the frequently occurring voice symptom *throat clearing or coughing*, as signs of excess mucus, whereas significantly less (17%) healthy subjects had symptoms (Simberg et al., 2009a). A similar association was also found in a review (Schneider et al., 2016). Whereas the causality is often suggested, it was not proved.

6.3 Voice Disorders in Relation to Stress at Work (Study I)

Stress at work was most significantly associated with voice disorders (OR 3.6). The results are in parallel to previous findings. In a Finnish study (Rantala et al., 2012), stress was the strongest risk factor for voice symptoms as assessed with a five-point scale, as done in this thesis. Stress was also a high-risk factor (OR 3.5) for voice problems in a large sample size (n = 1 878) (Kooijman et al., 2006), where stress was measured using one brief question and a five-point scale similar to the present study. The results are also in line with other findings regarding reactivity to stress being significantly more present in samples of teachers and teacher students with voice problems compared to those without problems (Gassull et al., 2010). Evaluated with the screening questionnaire, voice disorders associated with stress when evaluating using the variables *being strained or exhausted* and *nervous or tense in situations that requires talking* (all p values < 0.001) (Holmqvist et al., 2013). As the authors pointed out, the activation of the stress reaction, like in a strained situation in front of the public, could result any of the voice symptoms. The analysis regarding sex differences showed that stress, similar to voice disorders, was more prevalent in

females than in males. This is in line with the findings in the general population (n = 1 728) (Holmqvist et al., 2013). The females more often had both stress and voice disorders than the males in Study IV, whereas no elevated interaction association was found, as the prevalence of females was only 19% in those with both voice disorders and stress.

As found in Study I, reflux disease was more prevalent in the subjects with voice disorders. In addition, the subjects with rather or very much stress had significantly more reflux compared to those with not at all or little stress (14% versus 6%). This is supported by earlier findings, where reflux disease was associated with stress (OR 3.1) and also voice symptoms (OR 4.8) (Devadas et al., 2017). A similar association was suggested also in the general population of Finland (Holmqvist et al., 2013). The results, regarding the association between thyroid disease and voice disorders, were in line with previous studies showing that thyroid problems increased the risk for voice problems (Kadakia et al., 2013).

Overall, the results in Study I were in line with previous findings. The association with voice disorders was even stronger with stress than female sex, asthma, asthma medication, and allergic rhinitis, which are all known to be substantially associated with voice disorders. This was evident, even though the prevalence of diagnosed asthma was higher in the sample than in the general Finnish population (14% versus 9%) (*Asthma: Current Care Guidelines*, 2012). It should also be stated that stress was not mentioned in the title of the questionnaire or in the instructions. While stress was not highlighted, the association between stress and voice disorders can therefore be considered a very clear result of the questionnaire. Thus, stress at work may be a multidimensional problem associated with various variables and should be emphasized even more than estimated for voice disorders of teachers. Previous reports have discussed this interesting aspect between stress and voice symptoms. Not only stress may have an effect on the voice, but also the vocal quality might be a subject of stress (McAleavy et al., 2008). Future studies are recommended to investigate this problem with a follow-up design. This is more urgent, because recent studies show disconcerting findings of teachers' stress related to the COVID-19 pandemic and the new teaching environments that created disruptions in working arrangements, and these uncertainties have created a lot of strain in teaching work (Anderson et al., 2020; Ozamiz-Etxebarria et al., 2020). While the situation was problematic, teachers mostly experienced improvements in their voices, however (Nemr et al., 2021).

6.4 Voice Disorders in Relation to Indoor Environmental Quality (Study II)

Previously, vocal symptoms have played a minor role in studies related to the IEQ. The findings in the present thesis show an association between voice disorders and PIEQ and also indicate the association between voice disorders and the technically assessed poor condition of school buildings. The findings also show an agreement between perceived and technical assessments, and this is supported by the fact that the results of both assessments were only known to the authors and not to the teachers nor the technical experts. With these findings, the study provides new data in response to previous calls (Cantor Cutiva et al., 2013; Lin et al., 2020; Medeiros & Vieira, 2019; Wargocki et al., 2020).

As found in Study III, all the teachers with voice disorders reported significantly more PIEQ complaints than those without voice disorders. The *noise* and the *dust or dirt* were more prevalent, while the *smell of mold or an earthen cellar* was less prevalent compared to the reference data from school employees (Figure 2) (Tähtinen et al., 2020). A possible explanation could be due to the differences between the data used in Study II, using only primary and secondary schools, and the reference data with all kinds of schools. The majority of indoor air problems are reported to occur in primary and secondary school buildings in Finland (Korhonen et al., 2018), and it supports the findings in the present study.

Our results agree with previous findings from self-reported data. In 846 university teachers, the hoarseness was more prevalent related to poor circumstances such as stuffy or polluted air (p values < 0.05) (Korn et al., 2015). Development of voice symptoms associated with humidity (OR 1.8) and irritants (OR 1.5) in the classroom (Kooijman et al., 2006). The risk for voice disorders was twice as high in poor ventilated classroom compared to those with satisfactory ventilation in a random sample of 83 schools (n = 2 103) (de Medeiros et al., 2008). However, no correlations were found between clinical signs of voice disorders and humidity, dust, or chemical substances in a case-control study of 425 female teachers (Sliwinska-Kowalska et al., 2006). Noise is generally accepted to be associated with voice disorders, as the speaker has to raise and therefore strain her/his voice (Cantor Cutiva et al., 2013; Martins et al., 2014; Simberg et al., 2005; Vilkman, 2004). In a follow-up study (Simberg et al., 2005), noise was suggested as one of possible reasons for an increase in voice symptoms, as the number of complaints about noise increased from 40% to 54% over 12 years. Misbehavior of pupils was mentioned to possibly cause noise, in addition to stress (Simberg et al., 2005). In the present sample, the noise associated with stress. The association between a high background noise level is shown in schoolteachers in Denmark (Kristiansen et al., 2014), Italy (Puglisi et al., 2015), India (Devadas et al., 2017), and Brazil (de Medeiros et al., 2008).

The results of Study II suggested a possible association between technically assessed indoor air and the of occurrence of voice disorders. The results indicated that voice disorders might be more likely in the buildings with indoor air problems than in the buildings without such problems. Whereas there was a significant association between voice disorders and the poor conditions of the school buildings as a whole ($p = 0.010$), the confidence interval of adjusted relative risk (aRR) only amounted to < 1 between non-problem buildings and problem buildings (95% CI 0.99–1.64). Previous studies showed inconsistent results related to the association between voice problems and a poor IAQ that is assessed by using an external IAQ evaluation. Utilizing a voice ergonomic checklist that involves IAQ indicators together with the screening questionnaire, a poor IAQ associated with the higher risk of laryngitis (Rantala et al., 2012; Sala et al., 2009). No differences were found between voice problems and the humidity or CO_2 levels in the classrooms, when 14 teachers with voice problems were compared to 14 vocally healthy teachers (Lyberg Åhlander et al., 2014). As the authors noted, perceived dry air may also indicate generally dryer airway mucosa. Being that breathing through the nose is essential for moisturizing inhaled air, filtering it and to warm it, the authors suggested that breathing through the *mouth*, because of a blocked nose, may cause the feeling of dryness in the mouth and throat. As previously mentioned (Lyberg Åhlander et al., 2014), humidity measures are more complicated than the other IAQ measurements because of interactions with crowds, heating, and the weather.

The findings in Study II suggested that voice disorders were the most evident in the renovated buildings. As roughly hypothesized in the Aims section, the technically assessed poor condition of school buildings would be associated with voice disorders. In addition, it was found in a Cochrane review that the renovations would improve the symptoms rather than worsen them (Sauni et al., 2015). As expected, all the six complaints of PIAQ being *stuffy "bad" air, dry air, insufficient ventilation, smell of mold or an earthen cellar, other unpleasant odors, dust or dirt*, were more evident in the problem buildings than in the non-problem buildings. However, the complaints were mostly at the same level in the renovated buildings, as they were in the problem buildings. To compare to the values in the Finnish school staff in general, the *smell of mold or an earthen cellar* was clearly less prevalent compared to the reference data from school employees, however (6% versus 16%) (Tähtinen et al., 2020). Possible explanations can only be speculated on based on the cross-sectional study design. In general, mold odor in a building may indicate moisture damage and a higher risk for respiratory health effects, whether it is experienced by an occupant or a specialist (Cho et al., 2016; Mendell & Kumagai, 2017). For example, in Finland (Tähtinen et al., 2018), the employees were more likely to report mold odor in those parts of the buildings, where moisture damage was verified. However, some studies have suggested, yet not proved, that the concern

about the health effects of the indoor environment might increase the complaints such as smell of mold or the symptoms related to indoor environment (Bailer et al., 2008; Vuokko et al., 2015). Further studies are needed to assess the question with a longitudinal study design.

Other findings in pupils indicated a positive effect on health symptoms after a full renovation, whereas the symptoms improved only slightly after a partial renovation in another damaged school (Meklin et al., 2005). When focusing on the voice, changes in the vocal fold mucosa are associated with indoor air deficiencies (Vintturi et al., 2001; Witt et al., 2011; Wolkoff, 2018a). The ventilation may have been enhanced after the renovations, which is usual in Finland, and it may have decreased air humidity. Moreover, dust and its interactions with dry air may have related problems such as hyperfunctional changes in the voice (Geneid et al., 2009; Vilkman, 2004). The increased ventilation may also increase background noise. The background noise may lead to raising the voice in order to enhance the audibility, and this is called the Lombard effect (Patel & Schell, 2008). The interaction between ventilation and noise is also discussed, as the attendance of pupils, because the low ventilation rate can decrease attention (Mendell & Heath, 2005). In cases where the pupils have a decreased attention span, this could cause the pupils to be unsettled and noisy, and therefore the teachers have the need to use a louder voice (Haverinen-Shaughnessy et al., 2012). Even though the category *IA problems renovated* in the present study involved only buildings with completed, not partial, renovations, all the corrections may probably not have been carried out properly. With regard to moisture damage, it is known that a partial renovation does not improve health symptoms to the same extent as completed renovation (Meklin et al., 2005). After a renovation, the concentration of the volatile organic compounds (VOC) tends to be higher than usual and may cause irritation (Śmiełowska et al., 2017). Regarding other air impurities, previous findings have indicated that the mucosa of the upper airways may possibly heal very slowly in cases where a subject is exposed to building dampness for a long time (Rudblad et al., 2002). Whereas respiratory symptoms are suggested to improve to some extent when buildings are renovated because of mold and moisture damage (Sauni et al., 2015), hoarseness is found to remain (Patovirta et al., 2004a). Overall, the extensive use of the voice is a part of the explanation for voice disorders in teachers.

As stress was found to have a clear association with voice disorders in Studies I and IV and is supported also by previous findings, it is most likely also to be related to voice symptoms that are associated with a poor IEQ. In renovated buildings, the correction process may be protracted and contradictory and lasting for years with multiple frustrating phases. Experiences of prejudice have been reported by individuals, who have worked in buildings with suspected or observed indoor air problems, and who have suffered from health symptoms (Finell & Seppälä, 2018).

In the qualitative study, the subjects described how their experience was considered to be just a problematic case and given little empathy from colleagues or even from occupational health care professionals. Psychosocial parameters are suggested to be emphasized in workplaces along with indoor air problems, and employees, who had a negative perception of their psychosocial work environment, had more health symptoms associated with indoor air problems (Lahtinen, 2004). However, this finding was inconsistent with the recent results from Finnish employees, which indicated that while the office employees had more stress than the other employees, they reported environmental discomfort to a smaller extent than the others (n = 28 826) (Tähtinen et al., 2020). In the same study, the school staff had slightly less stress and more health symptoms than office workers and health care employees. The findings were also inconsistent with our results. Although the occurrence of stress was higher in the renovated buildings than in the problem buildings or non-problem buildings (36% versus 28%–19%) in Study II, the association was not significant. However, when the *stress at work* and *voice disorders* were combined in Study IV, the prevalence of the variable *combined stress and voice* was nearly three times higher in the renovated building than in the non-problem buildings that confirms the strong association between voice and stress.

Health is a multifaceted phenomenon with physical, mental, and social aspects (*WHO,* 2001) indicating that vocal health is a specific multidimensional issue (de Jong, 2010). Thus, any changes in aspects may have an impact on the voice. In teaching work, it is more than likely that employees face stressful situations as well as unwanted changes of the IEQ that associate potentially with prolonged and new voice problems. In addition, the IAQ complaints also associate with other symptoms and not only voice disorders (Tähtinen et al., 2020). It is essential to provide support for teachers in such situations. The proper support should not be targeted to only the voice but also to other physical, mental, and social issues. Social support at an organizational level could improve health symptoms related to the IAQ (Mendelson et al., 2000), and otherwise improve the well-being of teachers (Naghieh et al., 2015). While it is essential to provide proper management and renovation of the buildings (Fisk et al., 2007), it is also important to communicate openly about the conditions of and the renovations to the buildings, whether there are verified indoor air problems or not (Lahtinen et al., 2008, 2009). Voice symptoms may be harmful, although no associated indoor air exposure can be identified (Bakke et al., 2008). The consequences of poor IAQ are far-reaching in a school environment for the teachers' professional performance and even their ability to work. In addition, they are equally crucial for the learning process of pupils (Haverinen-Shaughnessy et al., 2011). Related to the learning environment, some of the renovation actions are more challenging, because along with implementing building maintenance, it is also

necessary to take into account the future needs of the pupils' learning environment (Korhonen et al., 2018).

6.4.1 The Relation between Perceived and Technical Assessments

The questionnaire data were validated by comparing the results with the technical assessment, as recommended (Haverinen-Shaughnessy et al., 2012). There was an agreement between perceived and technical assessments, and the teachers reported more PIAQ complaints in the school buildings with indoor air problems than in the other buildings.

Previous findings from other studies show inconsistent results. However, caution is needed when comparing studies with different study designs. Clinically assessed health symptoms in a university staff were compared to objective measurements in buildings with and without indoor air problems in a study by Bakke et al. (2008). The subjects in the problem buildings had more health symptoms compared to the other group. While the differences between the buildings were small, the exposure findings clearly varied between different rooms. The results in Study II were somewhat parallel with the findings in a study of Finnish hospital buildings (Hellgren et al., 2008). The staff reported more PIEQ complaints and health symptoms in the premises that needed further investigations than in the premises with no need of renovation. The most PIAQ complaints and symptoms were reported in the premises with the need of immediate renovations. Mainly, the subject of the problems was the ventilation system. The findings between different work environments are not fully comparable, however. In a school, the occupants are more active, and the buildings are more densely populated than in an office environment making the task of maintaining an acceptable IAQ difficult (Bayer et al., 2000). IAQ aspects, such as low ventilation rate, moisture problems, or air pollutants, can decrease attention (Mendell & Heath, 2005), whereas reducing CO_2 concentration by improving the ventilation rate in classrooms may improve the learning performance and attention of the pupils (Haverinen-Shaughnessy et al., 2011; Wargocki et al., 2020). When the decreased attention of pupils is demonstrated by them being unsettled and noisy, the teachers face the need to use a louder voice. The poor attention may also refer to the occupant density. The ventilation can change the air more efficiently, when there is a smaller group of pupils in a classroom compared to an area that is densely populated (Haverinen-Shaughnessy et al., 2012).

The technical assessment in Study II was based on the Finnish benchmarking system, which is regularly used to assess Finnish public buildings (THL, n.d.). However, while the experts were aware of the state of the buildings, there may be differences in how they assessed the level of a deficiency and what they assessed as

being an adequate renovation. Additionally, school buildings are large, and unknown deficiencies may exist in a building. The evaluation may be challenging, because of various interactions between the variables and individual differences (Bayer et al., 2000; Corgnati & da Silva, 2011; Vilkman, 2004). The challenges are well known (Haverinen-Shaughnessy et al., 2012; Sauni et al., 2015). In general, there are no unified guidelines on whether a renovation has been done properly, and all interested parties assess the buildings using different criteria. For example, those who are responsible for the maintenance of buildings concentrate on whether a repair is done correctly, whereas the occupational health authorities are interested in whether a building is healthy for the employees. This can also be seen in the inspection reports of the City's Environment Center and the benchmarking data of THL. The reports may vary depending upon how extensively and carefully the walk-through evaluations are carried out in the inspections, and the benchmarking data are then based on how school principals report these results. Although an external evaluation of the school buildings was utilized in the present thesis, there may have been problems in the buildings that the technical experts have missed. Notably, the inspection reports were only available for 41 of 67 buildings for the three years prior to the survey, although the Health Care Act (2010) requires monitoring the health and safety of the educational environment every three years. In addition, the data on the buildings, ventilation system, and repairs were inconsistent.

The least indoor air problems occurred in the buildings with not more than 200 pupils, and this is in line with reports provided by the Finnish benchmarking system, where it was noted that the deficiencies occurred more often in larger schools than in smaller schools (Rimpelä et al., 2007). According to the report, ventilation was sufficient only in 13% of the large schools supporting the findings in Study II, and it might be the air quality is affected by the number of people in the building than the building size. However, information concerning the pupils was available only for 52% of the buildings in Study II, and caution is needed in the interpretation.

The results show also that there were indoor air problems in more than half of the school buildings. The results were inconsistent with the findings of the international HITEA school study, where the occurrence of moisture damage varied between 24% and 41% as assessed by a trained staff (Haverinen-Shaughnessy et al., 2012). Likewise, the benchmarking data showed that the occurrence of deficiencies varied between 11% and 26% in the previous years (THL, n.d.). However, the data were collected at the school level and not at the school building level, as in Study II. The circumstances may vary substantially between the rooms, while the differences between the buildings are small (Bakke et al., 2008). As the data is utilized for both health promotion and research purposes (Finell et al., 2016; 2021), it was thought that it would benefit from more accurate collection. The old age of the buildings is one of the main problems causing poor IAQ (Tähtinen et al., 2018). Despite the fact

that the school buildings in Study II were younger than is the general case in Finland, the findings remain inconsistent with the other results. One possible explanation is the poor condition of the school buildings. As noted, main challenges in Finnish school buildings have been poor maintenance and insufficient ventilation (Kauppinen, 2013). The results in Study IV indicated that nearly half of the subjects, who worked in the non-problem buildings, had neither stress nor voice disorders. This finding, together with the previous recommendations (Fisk et al., 2007), supports the maintenance of school buildings and keeping them in good condition.

6.5 Work Ability in Teachers (Study III)

Assessing voice disorders in teachers becomes more relevant when focusing the impact on work performance (Sala et al., 2001). The results revealed that teachers with voice disorders assessed their work ability lower than their healthy colleagues, and there was significantly more absence due to sickness for those teachers with voice disorders than those without. The results are in line with previous findings, globally (n = 354–6 510), that work ability is decreased (Giannini et al., 2015) and absenteeism is more common (Behlau et al., 2012; Lyberg Åhlander et al., 2011; Medeiros & Vieira, 2019; van Houtte et al., 2011) in teachers with voice symptoms compared to the healthy teachers. The findings are mainly based on questionnaire studies (Behlau et al., 2012; Lyberg Åhlander et al., 2011; Medeiros & Vieira, 2019; van Houtte et al., 2011), but the results were also in line when utilizing a clinical evaluation of voice disorders (Giannini et al., 2015).

The results between the WAS and absence due to sickness were consistent, as the teachers with the lower WAS had more sick leave. The number of days of sick leave also corresponded to those of Finnish teachers in general (e.g., class teachers, mean 14 (95% CI 8–20) versus in general, mean 11 days per year) (Kouvonen et al., 2018). Teachers tend to have less sick leaves than, for example, office workers or health care employees (Cantor Cutiva & Burdorf, 2015; Nusseck et al., 2018). In Finland, schoolteachers had less absenteeism (9–13 days per year) than nurses (20–25 days per year), social workers (19 days per year), office workers (17 days per year), and even firefighters (18 days per year) (*Finnish Municipalities*, n.d.). Moreover, subject teachers had one of the lowest numbers of sick leave days in year 2019 (9 days per year) with only managers having less absence (8 days per year). Several possible explanations exist for this behavior. Teachers are either very much engaged in their work or have the feeling that they cannot afford to be away from work for one reason or another (Kauppinen et al., 2013; Thorsen et al., 2019). However, the findings are clearly different when absence due to sickness is focused on voice disorders. Teachers with voice problems have clearly more sick leave than healthy ones (de Medeiros et al., 2012; de Medeiros & Vieira, 2019; Lyberg

Åhlander et al., 2011). In the US (Roy et al., 2004a), 15% of teachers had from one to four days of absence because of voice disorders in the past year compared to 6% of non-teachers who were not working in education. Three percent of teachers and one percent of non-teachers had missed five or more days, respectively (p values < 0.001). Further, the severity of voice symptoms was found as an important predictor for sick leaves with the more severe the voice symptoms having the more absence due to sickness compared to mild symptoms (OR 8.0) (Cantor Cutiva & Burdorf, 2015). In addition, there was a clear association between voice disorders and decreased work ability (OR 12.2; $p < 0.0001$) (Giannini et al., 2015). Thus, there is an urgent need to pay attention to voice disorders when supporting work ability, and this is all the more worrying because teachers tend to be pleased with their job even though they consider that voice problems restrict their work (Lyberg Åhlander et al., 2011).

6.6 Work Ability in Relation to Voice Disorders, Stress at Work, and the Indoor Environmental Quality (Studies III and IV)

The results of the Study III showed a clear association between decreased work ability and voice disorders, stress at work, and a poor PIEQ. All associations between these variables were highly significant with p values of less than 0.0001. Stress at work was more prevalent with the poor PIEQ as well as with decreased work ability, and poor PIEQ was more prevalent in decreased work ability. Moreover, combining stress and voice disorders clearly had a stronger association with decreased work ability than if they had been evaluated separately, and nearly half of the subjects who worked in the non-problem buildings had neither stress nor voice disorders. Stress had the strongest association with WAS, and this is in agreement with previous studies (Kyriakou, 2011; Naghieh et al., 2015). Furthermore, teachers with rather or very much stress had more absence due to sickness than those with not at all or little stress. Females reported a lower WAS and more absence due to sickness than the males, being in line with previous studies (Ervasti et al., 2012; van Houtte et al., 2011).

In Study IV, a further investigation of the association between stress and voice disorders, as a combined variable, and work ability were conducted. The findings contributed to the results in Study III and demonstrated that combining stress and voice disorders has clearly a stronger association to decreased work ability than if they are evaluated separately. The work ability was the best in the teachers without voice disorders or stress, and the prevalence of absence due to sickness was also the lowest in this group. Stress was more likely in poor or moderate work ability than voice disorders.

Stress is present in teaching work and arises from the various demands of the work, for example, managing pupil misbehavior, the aims to provide high quality teaching for the pupils, the imbalance between demands and resources, and the heavy workload (Ervasti et al., 2012; Karasek, 1979; Kauppinen et al., 2013; Kyriacou, 2011; Santavirta et al., 2007). In a study from UK, the heavy workload was even found to be the most common reason for high turnover among teachers (Perryman & Calvert, 2020). In Finland, a study among physical education teachers revealed that while 80% of the 1 084 participants were satisfied with their work, 39% were still willing to leave the profession (Mäkelä et al., 2014).

The findings from the Study III related to the schools' IEQ are also of concern. Teachers, who reported a poor PIEQ, more often had a lower work ability and more sick leave than those working in good PIEQ. These findings agree with the studies when the IAQ was assessed by pupils (Ervasti et al., 2012) or by utilizing microbial investigations (Patovirta et al., 2004a). Further, more than half of the participants reported their voice getting worse in the workplace, and voice disorders were reported twice as often by the teachers working in poor PIEQ compared to those in good PIEQ. The vocal load related to the teaching work may be a part of the explanation. However, the associations between PIEQ and voice disorders as well as reduced work ability were very clear.

In a previous study, a reciprocal effect between voice and anxiety was suggested. While the quality of the voice was affected according to how the teachers experienced the condition of their voice, the quality of voice was also found to be a subject of anxiety (McAleavy et al., 2008). Although no causality can be assessed when utilizing a cross-sectional design, it is possible to speculate that there is a possibility of stress being both the cause and effect. Thus, when a teacher is on sick leave, she/he may prepare tasks for the pupils and wonder whether there are any replacement staff in the classroom or not. When the teacher returns to work and faces pupils that have become more unsettled during the days of absence, she/he may become even more stressed. To speculate further, although voice problems may repeatedly occur in the workplace and prolonged indoor environmental problems are frustrating, a subject may experience even more stress when the endless renovations are finally completed, and the focus is replaced by waiting for the signs of voice improvement.

As a result of the discussion, the work ability was the best in the teachers without voice disorders or stress at work, and the prevalence of absence due to sickness was also the lowest in this group. Voice disorders should not be taken as a natural part of a teaching job but rather as a good indicator of work ability. It is essential to take voice disorders as an occupational health question in teachers, especially when there are problems in the indoor environment (Lyberg Åhlander et al., 2011). In summary, there is a definite need of further studies to assess the effect of renovation on voice

symptoms and to investigate the interaction between voice disorders, stress, and the IEQ for work ability. Preventive actions for supporting vocal health and to reducing stress are recommended at an early stage in occupational health care.

6.7 Strengths and Limitations

The present thesis focuses only on epidemiological data of self-reported voice disorders, stress at work, and the IEQ. Recent studies have suggested that these variables associate with the work ability of teachers (Lin et al., 2020; Medeiros & Vieira, 2019; Wargocki et al., 2020). Undoubtedly, there are also other significant associated variables, such as the acoustical properties of the classroom (Lyberg Åhlander et al., 2011) and psychosocial (Lahtinen et al., 2002; Rezende et al., 2020) or as yet unknown aspects. However, the study focused more on the overall picture than the details.

One strength of the study was that it was conducted with a large sample in cities across Finland. The study sample size was the largest, where the screening questionnaire was utilized among teachers (Pekkarinen et al., 1992; Rantala et al., 2012, 2018; Sala et al., 2001; Simberg et al., 2005), and one of the largest conducted to study voice symptoms among teachers (Cantor Cutiva et al., 2013). Further, the study was conducted with validated, well-defined, and widely used questionnaires concerning work ability (Ahlstrom et al., 2010; Ilmarinen, 2009), PIEQ (Tähtinen et al., 2020) and stress at work (Elo et al., 2003). A further strength is the use of both the PIAQ and a technical assessment. In general, only self-reported data were utilized in studies focused on voice symptoms (de Medeiros et al., 2008; Kooijman et al., 2006; Korn et al., 2015). In addition, the technical experts were not aware of the results of the questionnaire nor were the teachers aware of the classification. The thermal conditions (ICQ) were not included in Study II. That was because the technical assessment was an overall evaluation of the deficiencies in the school buildings. In the whole study population, the temperature complaints, such as *temperature too high, varying room temperature, temperature too low*, were less evident than the other complaints, except for the *smell of mold or an earthen cellar* that had the lowest prevalence, and this was also found in the reference values (Tähtinen et al., 2020). However, the *smell of mold or an earthen cellar* was one of the PIAQ complaints and thus included in the perceived assessment.

For analysis purposes, three sum variables were constructed from the main variables. Voice disorders often contain different combinations of voice symptoms. The combination used for this thesis was based on two requirements being a version of the screening questionnaire, which is mostly used (Table 2) and including the symptom *morning hoarseness* to study its association with reflux (Sataloff et al., 2017; Simberg et al., 2001) which, in turn, associates with stress (Núñez-Rodríguez

& Sivelo, 2008). The two *hoarseness*-symptoms, *morning hoarseness* and *voice becomes low or hoarse*, were combined, because no significant differences were found, whether they were assessed as combined or separately. In addition to the voice disorders, the *combined stress and voice* as well as the *PIEQ index* were utilized to reflect the interaction regarding voice, stress, and the IEQ. In Study IV, stress and voice disorders were combined to study the strongest association with work ability. The variable *combined stress and voice* was proved beneficial, as it had a stronger association with decreased work ability than if *stress at work* and *voice disorders* were evaluated separately. The *PIEQ index* was then built to study the interaction between stress at work and voice disorders for work ability in Study III. The single-item variable allowed reflection on the interaction. In the questionnaire, altogether 11 questions were used to assess PIEQ. These were based on the MM 040 Questionnaire (Andersson, 1998), which consists of a wide range of environmental aspects used to assess indoor air problems in the workplace. As the main intent of Study III was to take into account all the three variables of interest, the index was a practical instrument to reflect the IEQ with sufficient accuracy, while simultaneously managing the three variables of interest. The composite variable was a meaningful grouping, where multiple possible outcomes were possible primary outcome variables, and any one of them were insufficient to represent association (Freemantle et al., 2003). In Study IV, *stress* and *voice disorders* were then combined to study the strongest association with work ability. The combined variable was proved beneficial, since by means of this variable, it was found that it had a stronger association with decreased work ability than if they are evaluated separately. However, the use of the index may have narrowed the interpretation (Song et al., 2013; van Droogenbroeck & Spruyt, 2015).

The response rate was smaller than expected (33%). It was low despite the questionnaire being conducted according to the recommendations (Fan & Yan, 2010) and sent to slightly more subjects than was evaluated for an adequate sample size (4 071 versus 4 000). For the non-response analysis (Aguinis et al., 2018), a brief questionnaire was sent to a random sample of 50 subjects not participating in the survey. Altogether, 11 (22%) responded. The main reasons for non-response were that teachers received too many surveys (n = 5) or were busy or that they forgot (n = 5). In the light of teaching work being very stressful (Karasek, 1979; Kauppinen et al., 2013; Kyriacou, 2011; Santavirta et al., 2007), the subjects with challenges, for example, voice or stress, might have moved to a different career or even retired, causing an effect on the sample. However, the present thesis contributes to the general proposition that both teachers and the general population receive too many surveys and are therefore often reluctant to participate in them all (Kumpulainen, 2017; Simberg et al., 2005; Sumecki et al., 2011). To compare the response rate to other email surveys, the response rate was 65% in a Public Health Cohort in Sweden,

which was distributed as a printed version to pensioners (Lyberg Åhlander et al., 2019), and in some studies, the response rate has been so low that the study is further conducted by contacting the participants in person (Greve et al., 2019). In Finnish email questionnaires for evaluating voice disorders, the response rate has been 22% among soccer coaches (Fellman & Simberg, 2017) and 44% in priests (Hagelberg & Simberg, 2015). In a review, it was found that the response rates were on average 11% lower in web surveys than in other survey methods (Manfreda et al., 2008). There are also contradictory findings, where the response rate in the web-based questionnaire was similar to a printed questionnaire (59% versus 56%) (Ohlsson et al., 2015).

Nevertheless, the low response rate may incur the risk that those who have voice disorders or experience poor indoor air in their classroom participated more actively in the study. The results may also have been affected by the fact that the subject title was named "Indoor questionnaire for teachers" when sending the questionnaire. This title may have motivated participation specifically from those who worked in schools with indoor air problems or suffered from respiratory or other symptoms. Thus, the perceived symptoms and complaints about PIEQ are possibly emphasized in the sample, causing potentially both a selection bias and an observation bias, also called the Hawthorne Effect (Payne & Payne, 2004; van Droogenbroeck & Spruyt, 2015). The Hawthorne effect explains the general effort made by individuals to modify their behavior when being observed leading to possible over or under-reporting. The effect may be especially present in sensitive issues such as work ability or stress.

However, it is suggested that over or under-reporting of symptoms and observations is an unlikely explanation regarding the associations between respiratory symptoms and moisture problems (Fisk et al., 2007). Further, the use of self-reports of doctor-diagnosed asthma and other diseases, may cause bias (Mendell et al., 2011) as is the case with an item interpretation that refers to the problem of whether the researcher and the participant have understood the question and answer in an exactly similar manner (Hardy & Ford, 2014). These concerns could be addressed in future studies by using more objective measures as either a single issue or in combination with the questionnaires.

The results are supported by a large and representative sample in Finland. Initially, the portion of female teachers was 81% (95% CI 79%–83%) compared with 79% in the general teachers population in Finland, and the study population was similar in age to teachers in general (mean age 44 years, SD 9.1 versus mean age 46 years, SD 9.2) (Kouvonen et al., 2018). In addition, the portion of class teachers was consistent with teachers in Finland (45% [95% CI 42%–48%] versus 44%) (Kumpulainen, 2017). The subsample in Study II was also representative in terms of professional subgroups (class teachers 43%; 95% CI 39%–47%), while the portion

of female teachers (85%; 95% CI 81%–87%) and the mean age (42 years; SD 9.5) differed slightly from the general statistics.

The mean WAS was 7.9 (SD 1.5; 95% CI 7.8–8.0), which is lower than for Finnish teachers in general at 8.3 (Kouvonen et al., 2016) and lower than reported in a recent study of Finnish teachers at 8.7 (Virtanen et al., 2020). However, there were clearly less absenteeism than Finnish teachers in general, as for example, class teachers had a mean of 8.1 (SD 11.1; 95% CI 7.2–9.1) (Kouvonen et al., 2018). The differences may be related to the fact that the findings were based on self-reported data, whereas the reference data were based on the employer's register. Thus, although the agreement between self-reported and the recorded number of days of sick leave has been assessed as being relatively good (Ferrie et al., 2005), some recall bias may have occurred.

Overall, the results confirmed the main hypotheses. Stress at work has the strongest association with voice disorders in teachers (Study I), poor PIAQ was associated with voice disorders, and there was an agreement between perceived and technical assessments (Study II). Further, decreased work ability in teachers was associated with voice disorders, stress at work, and a poor PIEQ (Study III), and stress and voice disorders together had a stronger association with decreased work ability than when they were evaluated separately (Study IV). In addition, the findings in Study II indicated a possible association between voice disorders and the technically assessed poor condition of school buildings. The results not only contribute to the previous findings on similar topics but also highlight the strong associations with voice problems, stress, and a poor IEQ for the decreased work ability of teachers. The results are supported by a large sample size and a very low amount of missing data from the questionnaires, because the participants answered almost every question. On the basis of the above evaluation, the results can be considered reliable. Hence, they can be generalized to primary and secondary education teachers in Finland and can also be used as indicative results regarding Finnish teachers in general, which is an occupational group of approximately 86 500 subjects (*Statistical Yearbook, 2020*).

6.8 Implications

There are no possibilities of making any conclusions about causality with a cross-sectional study design. Even though stress is assessed as potentially being both the cause and effect of voice disorders (Holmqvist-Jämsén et al., 2017b; Holmqvist et al., 2013; Vilkman, 2004), longitudinal research is needed to find a more accurate association between voice disorders and stress at work. However, the findings of this thesis could be utilized as a basis for new theoretical frameworks. Follow-up studies are also needed to investigate the causality between voice disorders and the effect of

renovations of the school building on voice symptoms. In addition, economical costs should be assessed to show the possible effect of renovations to teachers' voice disorders and work ability. Voice disorders, stress at work, and a poor IEQ may possibly act as a tangle having an impact on work ability. Follow-up studies are needed to investigate the causality of the interaction among these three variables for the work ability of teachers. It is also necessary to study other possible variables involved in producing tangles.

The short questionnaires were feasible for the participants, and they also provided accurate and reliable data, as they were validated with the exception for the screening questionnaire. However, the screening questionnaire has a significant association with the VHI questionnaire (Greve et al., 2019) and is supported with a laryngological evaluation once the questionnaire was developed (Sala et al., 2001). Further studies should include a more specific voice evaluation utilizing the Screen11 once it has been validated (Zenger, 2019) as well as IAQ assessments. In Finland, the inspection reports of the cities' Environment Centers would be a proper instrument to utilize in regular and consistent evaluations of working environments, provided that the inspections are adequately conducted and reported. Likewise, the benchmarking data could provide new opportunities for research studies when adequately collected. The single-item *PIEQ index* allowed reflection on the interaction between voice disorders, stress, and the work ability, and was a practical instrument to indicate the IEQ. Future studies may also wish to investigate the validity and reliability of the index.

Voice disorders in teachers should be taken as an occupational as well as a health question. Voice disorders seem to be good indicators for the work ability and should thus be taken seriously. The findings of the present thesis and the previous results (Pekkarinen et al., 1992; Simberg et al., 2005) indicate that the occurrence of teachers' voice disorders have increased constantly since 1988 till today. Hence, the subjects with voice problems should be found at an early stage to provide proper support. The questionnaire that was used in this study was initially developed for finding potential risk groups (Simberg et al., 2001). It is a fast and easily administered instrument for the systematic screening of the voice. Even with the limitations mentioned, it is a practical instrument for the regular use in occupational health care. The use of the screening questionnaire together with a stress questionnaire is recommended, as the combination of voice disorders, and stress has a stronger association with work ability than only voice disorders.

This thesis shows the need of protective actions in teaching work. Continuous and regular vocal training between working hours in cooperation with teachers is recommended. As has been noted previously (Ilomäki, 2008), two out of three teachers have never had voice training. Providing targeted coaching for teachers is recommended as one of the occupational health activities for primary prevention.

Other voice-ergonomic interventions are also welcome such as reducing stress and improving the IEQ. To find the risk groups, regular voice screenings should be implemented. All actions are recommended to be performed in cooperation with employees, occupational health care professionals, and employers. Effective work ability support is not only a responsibility of occupational health care but also requires actions by employers who are, in fact, responsible for the health and safety of employees.

According to the results, there were indoor air problems in more than half of the school buildings with the majority of indoor air problems being reported as occurring in primary and secondary school buildings in Finland (Korhonen et al., 2018). In contrast, nearly half of the subjects, who worked in the non-problem buildings, had neither stress nor voice disorders. Thus, the maintenance and repair of school buildings are essential and have to be taken into consideration throughout the budget preparation process. In addition, open communication about the condition of the school building and renovation activities is important, as the correction process may be protracted, contradictory, and frustrating.

7 Conclusions

In this thesis, voice disorders were studied together with stress at work and the IEQ, and their association with the work ability among Finnish teachers. Using a large sample size of 1 198 primary and secondary school teachers and a subsample (n_t = 538), voice disorders, stress at work, and work ability were assessed by means of well-defined and concise questionnaires, and the IEQ assessments were conducted utilizing both perceived and technical evaluations. The findings show that more than half (54%) of Finnish teachers suffered from voice disorders. Compared to the previous findings with the screening questionnaire (Pekkarinen et al., 1992; Simberg et al., 2005), the results may indicate a continuous increase in the prevalence of teachers' voice disorders.

As a whole, voice disorders, stress at work, and the poor PIEQ are all clearly associated with the work ability of teachers. Stress at work has the strongest association with voice disorders, and stress and voice disorders together have an even stronger association with decreased work ability than when they were evaluated separately. Nearly half of the subjects working in the non-problem buildings have neither stress nor voice disorders. The results contribute to earlier findings regarding the strong association between voice disorders and stress as well as voice disorders and decreased work ability.

Vocal symptoms have played a minor role in studies related to the IEQ. The findings of the present study support previous data concerning the association between voice disorders and the poor IEQ in the workplace and suggest for further research studies in this field (Cantor Cutiva et al., 2013; Lin et al., 2020; Medeiros & Vieira, 2019; Wargocki et al., 2020). The results show that teachers with voice problems reported significantly more indoor environment complaints than those without voice disorders. The results also indicated a possible association between a technically assessed poor condition of school buildings and voice disorders. As found in this study, there is an agreement between perceived and technical assessments. The results also showed that there were indoor air problems in more than half of the school buildings. Whereas the occurrence of air quality problems appears to be relatively high, it seems that the majority of indoor air problems are

reported to occur in primary and secondary school buildings in Finland (Korhonen et al., 2018).

On the basis of available information, this is the first study to date where the interaction between voice disorders, stress at work, the IEQ, and work ability have been evaluated. This study advances our understanding of teachers' work ability, highlighting particularly the relation between voice disorders and stress to work ability in teachers. The results indicate that stress at work may be a multidimensional problem associated with various variables and should be emphasized even more than estimated for voice disorders and the work ability of teachers. Moreover, the findings raise the question of whether voice disorders, stress at work, and a poor IEQ act as a tangle that would have an association with work ability that is more than the sum of its parts causing a potential hazard to the work ability of teachers.

A well-functioning voice is an essential tool in the teaching profession, not only for the high quality of teaching, but also for effective learning. It is therefore apparent that protective actions and improvements would ensure the well-being of teachers and pupils. A continuous vocal load together with stress and a poor IEQ, in addition to asthma and other health issues, are potential hazards for a proper working environment and the ability to work. The individual burden of these issues is a major problem, but the economic costs due to a sickness absence and possible early withdrawal from the teaching profession must also be considered. Thus, preventive actions for supporting vocal health and to reducing stress are recommended at an early stage in occupational health care.

Teacher's voice problems often cause a reaction such as "every teacher has hoarseness." This attitude has to be changed to be understanding with reactions like "what could we do for it?" and then the provision of proper support to all who need it should be supplied. As the work ability was the best in the participants without voice disorders or stress at work, the teachers need preventive actions to protect their voice, which is their primary working tool.

Acknowledgements

This study was carried out at the Faculty of Medicine, University of Turku. I want to express my warm thanks to the Finnish Work Environment Fund, the Juho Vainio Foundation, and the Clinical Research Centre, University of Turku for supporting this work.

I express my sincerest gratitude to my supervisors Professor Tuula Putus and Professor emeritus Jukka Uitti, who have kindly offered the supervision and support during the research process and have stimulated very interesting discussions. I am very grateful for having the opportunity to work with you both. I want to offer my special thanks to Tuula for all the good advice and to Jukka for the encouragement.

My sincerest thanks go to Eliisa Löyttyniemi for introducing me to biostatistics. I am thankful of your never-ending patience in answering all my questions and unfailing support as well as fascinating discussions on sewing issues.

I am sincerely grateful for Professor Anne-Maria Laukkanen and Professor Elina M. Toskala for your work as pre-examiners. I appreciate very much your comments and suggestions to improve the work, and it was a pleasure to work with you! I would also like to greatly acknowledge Professor Viveka Lyberg Åhlander for agreeing to act as my opponent at the public defense.

I warmly thank the follow-up committee members, Professor emerita Susanna Simberg, Professor Jyrki Liesivuori, and Professor Jussi Vahtera for their valuable work and especially the discussions we had. I am especially grateful to Susanna for the comments on my research papers. A heartfelt thanks goes to Elizabeth Nyman for the language checking and all the encouragement you gave me! I also want to thank Robert M. Badeau for providing an additional language checking service.

I have enjoyed very much the research seminars with their inspiring discussions and feedback. I express my warm thanks to my supervisors Tuula and Jukka and the attendees of their seminars at the University of Turku and the University of Tampere. I also warmly thank Professor emeritus Pertti Järvinen for your valuable comments and the support, as well as your seminar group.

I warmly thank The Finnish Society for Voice Ergonomics and the members of the board for sharing your expertise. My special thanks to Terhi Ansamaa, Sirpa Pirilä, and Jaana Tyrmi for cooperation and the cheerful moments we have shared.

There are people around me who have made valuable contributions at some point in the process. I am very grateful to Ahmed Geneid, Juha Vintturi, Maaria Ansaranta, Annika Laaksonen, Tiia Ojala, and Ketaki Phadke from HUS Phoniatrics for the opportunity to do research with you and to learn from your extensive knowledge in the field of voice dysfunctions. I would like to thank Assistant Professor Heidi Salonen and Associate Professor Risto Kosonen from Aalto University for introducing to me environmental questions. I warmly thank Anna Beronius from my studies at Karolinska Institute. A special thanks to Anita McAllister for the enjoyable dinner!

I would like to acknowledge all the teachers who participated in the study. You made this scientific work possible, and I truly appreciate your contribution. My warmest thanks to the principals who informed and encouraged their teachers to participate in the study. I am very grateful to the experts who provided the evaluation of the school buildings. I also want to express my thanks to the cities where the study was carried out for providing excellent cooperation during this project. I want to express special thanks to the education departments, the Real Estate Centers, and the Environment Centers and their friendly employees for providing information and help for the study. I would also like to thank all who have contributed to the project by providing cooperation, support, encouragement, or just good conversations including Leila Kakko, Anne-Marie Kurka, Riina Länsikallio, Arto Martikainen, Tuula Oksanen, Eero Palomäki, and all my colleagues. My special thanks to Sara Vertanen and Ville Hakulinen for forming the vision in my mind to an impressive cover image.

I am privileged to have dear friends in my life. Thank you for having time for me unless I have not always had time for you.

This work is dedicated to my loved ones. Thank you for the support, encouragement, and joy you have brought into my life. I am privileged to have you all in my life. Thank you for just being there.

Helsinki, August 2021
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References

Aguinis, H., Ramani, R. S., & Alabduljader, N. (2018). What You See Is What You Get? Enhancing Methodological Transparency in Management Research. *Academy of Management Annals*, *12*(1), 83–110. https://doi.org/10.5465/annals.2016.0011

Ahlstrom, L., Grimby-Ekman, A., Hagberg, M., & Dellve, L. (2010). The work ability index and single-item question: associations with sick leave, symptoms, and health: A prospective study of women on long-term sick leave. *Scandinavian Journal of Work, Environment & Health*, *36*(5), 404–412. https://doi.org/10.5271/sjweh.2917

Alaluusua, S., & Johannson, M. (2003). *Psycho-social handicap of voice disorder and its rehabilitation: a pilot study of Finnish version of Voice Handicap Index [In Finnish]*. Institute of Behavioral Sciences, University of Helsinki.

Anderson, R. C., Bousselot, T., Katz-Buoincontro, J., & Todd, J. (2020). Generating Buoyancy in a Sea of Uncertainty: Teachers Creativity and Well-Being During the COVID-19 Pandemic. *Frontiers in Psychology*, *11*, 614774. https://doi.org/10.3389/fpsyg.2020.614774

Andersson, K. (1998). Epidemiology approach on indoor air problems. *Indoor Air*, *Suppl. 4*, 32–39.

Andersson, K., Stridh, G., Fagerlund, I., & Aslaksen, W. (n.d.). *Manual School Environment. MM Questionnaire.* http://www.mmquestionnaire.se/manuals/school_environment.pdf

Angelillo, M., Di Maio, G., Costa, G., Angelillo, N., & Barillari, U. (2009). Prevalence of occupational voice disorders in teachers. *Journal of Preventive Medicine and Hygiene*, *50*(1), 26–32. https://core.ac.uk/download/pdf/234784693.pdf

Aronson, A. E., & Bless, D. M. (2009). *Clinical voice disorders* (4th ed.). Thieme.

ASHRAE. (2010). *Ventilation for Acceptable Indoor Air Quality*. American Society of Heating and Air-Conditioning Engineers Inc., Atlanta.

Asthma. Current Care Guidelines. Working group set up by the Finnish Medical Society Duodecim, The Finnish Respiratory Society, The Finnish Paediatric Society, and The Finnish Society of Clinical Physiology. (2012). Helsinki: The Finnish Medical Society Duodecim. www.kaypahoito.fi

Asumisterveysasetus [Decree of the Ministry of Social Affairs and Health on Health-related Conditions of Housing and Other Residential Buildings and Qualification.], Pub. L. No. 545 (2015). https://www.finlex.fi/en/laki/kaannokset/2015/en20150545.pdf

Bailer, J., Witthöft, M., & Rist, F. (2008). Modern health worries and idiopathic environmental intolerance. *Journal of Psychosomatic Research*, *65*(5), 425–433. https://doi.org/10.1016/j.jpsychores.2008.05.006

Baker, J. (2008). The role of psychogenic and psychosocial factors in the development of functional voice disorders. *International Journal of Speech-Language Pathology*, *10*(4), 210–230. https://doi.org/10.1080/17549500701879661

Bakke, J. V, Norback, D., Wieslander, G., Hollund, B.-E., Florvaag, E., Haugen, E. N., & Moen, B. E. (2008). Symptoms, complaints, ocular and nasal physiological signs in university staff in relation to indoor environment: temperature and gender interactions. *Indoor Air*, *18*(2), 131–143. https://doi.org/10.1111/j.1600-0668.2007.00515.x

Bayer, C. W., Crow, S. A., & Fischer, J. (2000). *Causes of Indoor Air Quality Problems in Schools. Summary of Scientific Research. Revised Edition.* U.S. Department of Energy. http://doas-radiant.psu.edu/ornl_m6633_r1.pdf

Behlau, M., Zambon, F., Guerrieri, A. C., & Roy, N. (2012). Epidemiology of voice disorders in teachers and nonteachers in Brazil: prevalence and adverse effects. *Journal of Voice*, *26*(5), 665.e9-18. https://doi.org/10.1016/j.jvoice.2011.09.010

Bellingrath, S., & Kudielka, B. M. (2017). Biological Pathways to Stress-Related Disease Vulnerability in Educators. In T. M. McIntyre, S. E. McIntyre, & D. J. Francis (Eds.), *Educator Stress: An Occupational Health Perspective*. Springer International Publishing AG. https://doi.org/10.1007/978-3-319-53053-6_4

Besser, A., Lotem, S., & Zeigler-Hill, V. (2020). Psychological Stress and Vocal Symptoms Among University Professors in Israel: Implications of the Shift to Online Synchronous Teaching During the COVID-19 Pandemic. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2020.05.028

Bottalico, P., & Astolfi, A. (2012). Investigations into vocal doses and parameters pertaining to primary school teachers in classrooms. *The Journal of the Acoustical Society of America*, *131*(4), 2817–2827. https://doi.org/10.1121/1.3689549

Brink, H. W., Loomans, M. G. L. C., Mobach, M. P., & Kort, H. S. M. (2020). Classrooms' indoor environmental conditions affecting the academic achievement of students and teachers in higher education: A systematic literature review. *Indoor Air*. https://doi.org/10.1111/ina.12745

Byeon, H. (2019). The Risk Factors Related to Voice Disorder in Teachers: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health*, *16*(19). https://doi.org/10.3390/ijerph16193675

Cantor Cutiva, L. C., & Burdorf, A. (2015). Medical Costs and Productivity Costs Related to Voice Symptoms in Colombian Teachers. *Journal of Voice*, *29*(6), 776.e15-776.e22. https://doi.org/10.1016/j.jvoice.2015.01.005

Cantor Cutiva, L. C., Vogel, I., & Burdorf, A. (2013). Voice disorders in teachers and their associations with work-related factors: a systematic review. *Journal of Communication Disorders*, *46*(2), 143–155. https://doi.org/10.1016/j.jcomdis.2013.01.001

Casper, J. K. (2001). Treatment outcomes in occupational voice disorders. In P. H. Dejonckere (Ed.), *Occupational Voice: Care and Cure*. Kugler Publications.

Chen, S. H., Chiang, S. C., Chung, Y. M., Hsiao, L. C., & Hsiao, T. Y. (2010). Risk Factors and Effects of Voice Problems for Teachers. *Journal of Voice*, *24*(2), 183–192. https://doi.org/10.1016/j.jvoice.2008.07.008

Cho, S. J., Cox-Ganser, J. M., & Park, J.-H. (2016). Observational scores of dampness and mold associated with measurements of microbial agents and moisture in three public schools. *Indoor Air*, *26*(2), 168–178. https://doi.org/10.1111/ina.12191

Chong, E. Y. L., & Chan, A. (2010). Subjective Health Complaints of Teachers From Primary and Secondary Schools in Hong Kong. *International Journal of Occupational Safety and Ergonomics*, *16*, 23–39.

Cohen, S. M., Kim, J., Roy, N., Asche, C., & Courey, M. (2012). Prevalence and causes of dysphonia in a large treatment-seeking population. *Laryngoscope*, *122*(2), 343–348. https://doi.org/10.1002/lary.22426

Corgnati, S. P., & da Silva, M. G. (Eds.). (2011). *Indoor Climate Quality Assessment. REHVA Guidebook.* REHVA, Federation of European Heating, Ventilation and Air–conditioning Associations.

Cox, T., Griffiths, A., & Rial-Gonzalez, E. (2000). *Research on work-related stress*. Office for Official Publications of the European Communities.

Cutiva, L. C. C., & Burdorf, A. (2016). Work-Related Determinants of Voice Complaints Among School Workers: An Eleven-Month Follow-Up Study. *American Journal of Speech-Language Pathology*, *25*(4), 590–597. https://doi.org/10.1044/2016_AJSLP-14-0191

Da Costa, V., Prada, E., Roberts, A., & Cohen, S. (2012). Voice disorders in primary school teachers and barriers to care. *Journal of Voice*, *26*(1), 69–76. https://doi.org/10.1016/j.jvoice.2010.09.001

de Jong, F. I. C. R. S. (2010). An introduction to the teacher's voice in a biopsychosocial perspective. In *Folia Phoniatrica et Logopaedica* (Vol. 62, Issues 1–2, pp. 5–8). https://doi.org/10.1159/000239058

de Jong, F. I. C. R. S., Kooijman, P. G. C., Thomas, G., Huinck, W. J., Graamans, K., & Schutte, H. K. (2006). Epidemiology of voice problems in Dutch teachers. *Folia Phoniatr Logop*, *58*. https://doi.org/10.1159/000091732

de Medeiros, A. M., Assuncao, A. Á., & Barreto, S. M. (2012). Absenteeism due to voice disorders in female teachers: A public health problem. *International Archives of Occupational and Environmental Health*, *85*(8), 853–864. https://doi.org/10.1007/s00420-011-0729-1

de Medeiros, A. M., Barreto, S. M., & Assuncao, A. A. (2008). Voice disorders (dysphonia) in public school female teachers working in Belo Horizonte: prevalence and associated factors. *Journal of Voice*, *22*(6), 676–687. https://doi.org/10.1016/j.jvoice.2007.03.008

de Medeiros, A. M., & Vieira, M. de T. (2019). Work absenteeism due to voice disorders in Brazilian schoolteachers. *Cadernos de Saude Publica*, *35Suppl 1*(Suppl 1), e00171717. https://doi.org/10.1590/0102-311X00171717

Deary, I. J., Webb, A., Mackenzie, K., Wilson, J. A., & Carding, P. N. (2004). Short, Self-Report Voice Symptom Scales: Psychometric Characteristics of the Voice Handicap Index-10 and the Vocal Performance Questionnaire. *Otolaryngology–Head and Neck Surgery*, *131*(3), 232–235. https://doi.org/10.1016/j.otohns.2004.02.048

Deary, I. J., Wilson, J. A., Carding, P. N., & MacKenzie, K. (2003). VoiSS: A patient-derived Voice Symptom Scale. *Journal of Psychosomatic Research*, *54*(5), 483–489. https://doi.org/10.1016/S0022-3999(02)00469-5

Definitions of communication disorders and variations [Relevant Paper]. (1993). American Speech-Language-Hearing Association [ASHA]. http://www.asha.org/policy/RP1993-00208/

Dejonckere, P. H. (2001a). Gender differences in the prevalence of occupational voice disorders. In P. H. Dejonckere (Ed.), *Occupational Voice: Care and Cure*. Kugler Publications.

Dejonckere, P. H. (2001b). Introduction: The concept of occupational voice disorders. In P. H. Dejonckere (Ed.), *Occupational Voice: Care and Cure*. Kugler Publications.

Devadas, U., Bellur, R., & Maruthy, S. (2017). Prevalence and Risk Factors of Voice Problems Among Primary School Teachers in India. *Journal of Voice*, *31*(1), 117.e1-117.e10. https://doi.org/10.1016/j.jvoice.2016.03.006

Dietrich, M., & Verdolini, K. A. (2012). Vocal Function in Introverts and Extraverts During a Psychological Stress Reactivity Protocol. *Journal of Speech, Language, and Hearing Research*, *55*(3), 973–987. https://doi.org/10.1044/1092-4388(2011/10-0344)

Elo, A.-L., Leppänen, A., & Jahkola, A. (2003). Validity of a single-item measure of stress symptoms. *Scandinavian Journal of Work, Environment & Health*, *29*(6), 444–451. https://doi.org/10.5271/sjweh.752

Elo, A.-L., Leppanen, A., Lindstrom, K., & Ropponen, T. (1992). *Occupational Stress Questionnaire (OSQ)— User's Instructions* (Reviews 19).

Elo, A.-L., Leppänen, A., & Sillanpää, P. (1998). Applicability of survey feedback for an occupational health method in stress management. *Occupational Medicine*, *48*(3), 181–188. https://doi.org/10.1093/occmed/48.3.181

Ervasti, J., Kivimäki, M., Kawachi, I., Subramanian, S. V, Pentti, J., Oksanen, T., Puusniekka, R., Pohjonen, T., Vahtera, J., & Virtanen, M. (2012). School environment as predictor of teacher sick leave: data-linked prospective cohort study. *BMC Public Health*, *12*(1), 770. https://doi.org/10.1186/1471-2458-12-770

Fan, W., & Yan, Z. (2010). Factors affecting response rates of the web survey: A systematic review. *Computers in Human Behavior*, *26*(2), 132–139. https://doi.org/10.1016/j.chb.2009.10.015

Fellman, D., & Simberg, S. (2017). Prevalence and Risk Factors for Voice Problems Among Soccer Coaches. *Journal of Voice*, *31*(1), 121.e9-121.e15. https://doi.org/10.1016/j.jvoice.2016.02.003

Ferrie, J. E., Kivimaki, M., Head, J., Shipley, M. J., Vahtera, J., & Marmot, M. G. (2005). A comparison of self-reported sickness absence with absences recorded in employers' registers: evidence from the Whitehall II study. *Occupational and Environmental Medicine*, *62*(2), 74–79. https://doi.org/10.1136/oem.2004.013896

Finell, E., Haverinen-Shaughnessy, U., Tolvanen, A., Laaksonen, S., Karvonen, S., Sund, R., Saaristo, V., Luopa, P., St??hl, T., Putus, T., & Pekkanen, J. (2016). The associations of indoor environment and psychosocial factors on the subjective evaluation of Indoor Air Quality among lower secondary school students: a multilevel analysis. *Indoor Air*, *March*, 1–9. https://doi.org/10.1111/ina.12303

Finell, E., & Seppälä, T. (2018). Indoor air problems and experiences of injustice in the workplace: A quantitative and a qualitative study. *Indoor Air*, *28*(1), 125–134. https://doi.org/10.1111/ina.12409

Finell, E., Tolvanen, A., Ikonen, R., Pekkanen, J., & Ståhl, T. (2021). Students' school-level symptoms mediate the relationship between a school's observed moisture problems and students' subjective perceptions of indoor air quality. *Indoor Air*, *31*(1), 40–50. https://doi.org/10.1111/ina.12711

Finkelhor, B. K., Titze, I. R., & Durham, P. L. (1988). The effect of viscosity changes in the vocal folds on the range of oscillation. *Journal of Voice*, *1*(4), 320–325. https://doi.org/10.1016/S0892-1997(88)80005-5

Fisher, G. G., Matthews, R. A., & Gibbons, A. M. (. (2016). Developing and investigating the use of single-item measures in organizational research. *Journal of Occupational Health Psychology*, *21*(1), 3–23. https://doi.org/10.1037/a0039139

Fisk, W. J., Lei-Gomez, Q., & Mendell, M. J. (2007). Meta-analyses of the associations of respiratory health effects with dampness and mold in homes. *Indoor Air*, *17*(4), 284–296. https://doi.org/10.1111/j.1600-0668.2007.00475.x

Francis, D. O., Daniero, J. J., Hovis, K. L., Sathe, N., Jacobson, B., Penson, D. F., Feurer, I. D., & McPheeters, M. L. (2017). Voice-Related Patient-Reported Outcome Measures: A Systematic Review of Instrument Development and Validation. *Journal of Speech, Language, and Hearing Research*, *60*(1), 62–88. https://doi.org/10.1044/2016_JSLHR-S-16-0022

Frankenhaeuser, M., & Gardell, B. (1976). Underload and Overload in Working Life: Outline of a Multidisciplinary Approach. *Journal of Human Stress*, *2*(3), 35–46. https://doi.org/10.1080/0097840X.1976.9936068

Freemantle, N., Calvert, M., Wood, J., Eastaugh, J., & Griffin, C. (2003). Composite Outcomes in Randomized Trials: Greater Precision But With Greater Uncertainty? *The Journal of the American Medical Association*, *289*(19), 2554–2559. https://doi.org/10.1001/jama.289.19.2554

French, J., W, R., & Cobb, S. (1981). A model of person-environment fit. In L. Levi (Ed.), *Society, stress and disease; vol 4 (Working life)*. Oxford University Press.

Gadepalli, C., Fullwood, C., Ascott, F., & Homer, J. J. (2019). Voice burden in teachers and non-teachers in a UK population: A questionnaire-based survey. *Clinical Otolaryngology*, *44*(6), 1045–1058. https://doi.org/10.1111/coa.13437

Galton, M. J., & MacBeath, J. (2008). *Teachers Under Pressure*. SAGE Publications Ltd STM. http://ebookcentral.proquest.com/lib/kutu/detail.action?docID=465093.

Gassull, C., Casanova, C., Botey, Q., & Amador, M. (2010). The impact of the reactivity to stress in teachers with voice problems. *Folia Phoniatrica et Logopaedica*, *62*(1–2), 35–39. https://doi.org/10.1159/000239061

Geneid, A., Ronkko, M., Airaksinen, L., Voutilainen, R., Toskala, E., Alku, P., & Vilkman, E. (2009). Pilot study on acute voice and throat symptoms related to exposure to organic dust: preliminary findings from a provocation test. *Logoped Phoniatr Vocol*, *34*(2), 67–72. https://doi.org/10.1080/14015430902845711

Giannini, S. P. P., Latorre, M. D. R. D. D. O., Fischer, F. M., Ghirardi, A. C. D. A. M., & Ferreira, L. P. (2015). Teachers' voice disorders and loss of work ability: a case-control study. *Journal of Voice*, *29*(2), 209–217. https://doi.org/10.1016/j.jvoice.2014.06.004

Godwin, C., & Batterman, S. (2007). Indoor air quality in Michigan schools. *Indoor Air*, *17*(2), 109–121. https://doi.org/10.1111/j.1600-0668.2006.00459.x

Goldstein, D. S., & McEwen, B. (2002). Allostasis, Homeostats, and the Nature of Stress. *Stress*, *5*(1), 55–58. https://doi.org/10.1080/102538902900012345

Greve, K., Bryn, E. K., & Simberg, S. (2019). Voice disorders and impact of voice handicap in Norwegian student teachers. *Journal of Voice*, *33*(4), 445–452. https://doi.org/10.1016/j.jvoice.2018.01.019

Grynderup, M. B., Nabe-Nielsen, K., Lange, T., Conway, P. M., Bonde, J. P., Francioli, L., Garde, A. H., Kaerlev, L., Rugulies, R., Vammen, M. A., Hgh, A., & Hansen, Å. M. (2016). Does Perceived Stress Mediate the Association Between Workplace Bullying and Long-Term Sickness Absence? *Journal of Occupational and Environmental Medicine*, *58*(6). https://journals.lww.com/joem/Fulltext/2016/06000/Does_Perceived_Stress_Mediate_the_Association.24.aspx

Guidetti, G., Viotti, S., Bruno, A., & Converso, D. (2018). Teachers' work ability: a study of relationships between collective efficacy and self-efficacy beliefs. *Psychology Research and Behavior Management*, *11*, 197–206. https://doi.org/10.2147/PRBM.S157850

Hackenberg, S., Hacki, T., Hagen, R., & Kleinsasser, N. H. (2010). Voice disorders in asthma. *Laryngo- Rhino- Otologie*, *89*(8), 460—464. https://doi.org/10.1055/s-0030-1249694

Hagelberg, A.-M., & Simberg, S. (2015). Prevalence of voice problems in priests and some risk factors contributing to them. *Journal of Voice*, *29*(3), 389.e11-8. https://doi.org/10.1016/j.jvoice.2014.08.015

Hämmig, O. (2017). Health and well-being at work: The key role of supervisor support. *SSM - Population Health*, *3*, 393–402. https://doi.org/10.1016/j.ssmph.2017.04.002

Hardy, B., & Ford, L. R. (2014). It's not me, it's you: miscomprehension in surveys. *Organizational Research Methods*, *17*(2), 138–162. https://doi.org/10.1177/1094428113520185

Harris, D. N., & Adams, S. J. (2007). Understanding the level and causes of teacher turnover: A comparison with other professions. *Economics of Education Review*, *26*(3), 325–337. https://doi.org/10.1016/j.econedurev.2005.09.007

Haverinen-Shaughnessy, U., Borras-Santos, A., Turunen, M., Zock, J. P., Jacobs, J., Krop, E. J. M., Casas, L., Shaughnessy, R., Täubel, M., Heederik, D., Hyvärinen, A., Pekkanen, J., & Nevalainen, A. (2012). Occurrence of moisture problems in schools in three countries from different climatic regions of Europe based on questionnaires and building inspections: the HITEA study. *Indoor Air*, *22*(6), 457–466. https://doi.org/10.1111/j.1600-0668.2012.00780.x

Haverinen-Shaughnessy, U., Moschandreas, D. J., & Shaughnessy, R. J. (2011). Association between substandard classroom ventilation rates and students' academic achievement. *Indoor Air*, *21*(2), 121–131. https://doi.org/10.1111/j.1600-0668.2010.00686.x

Hellgren, U.-M., Eero, P., Lahtinen, M., Henri, R., & Reijula, K. (2008). Complaints and symptoms among hospital staff in relation to indoor air and the condition and need for repairs in hospital buildings. *SJWEH Supplements*, *4*, 58–63.

Hemler, R. J., Wieneke, G. H., Lebacq, J., & Dejonckere, P. H. (2001). Laryngeal mucosa elasticity and viscosity in high and low relative air humidity. *Eur Arch Otorhinolaryngol*, *258*(3), 125–129. https://link.springer.com/content/pdf/10.1007/s004050100321.pdf

Holmqvist-Jämsén, S., Johansson, A., Santtila, P., Westberg, L., von der Pahlen, B., & Simberg, S. (2017a). Investigating the Role of Salivary Cortisol on Vocal Symptoms. *Journal of Speech, Language, and Hearing Research*, *60*(10), 2781–2791. https://doi.org/10.1044/2017_JSLHR-S-16-0058

Holmqvist-Jämsén, S., Johansson, A., Westberg, L., Santtila, P., von der Pahlen, B., & Simberg, S. (2017b). Associations Between Vocal Symptoms and Genetic Variants in the Oxytocin Receptor

and Arginine Vasopressin 1A Receptor Gene. *Journal of Speech, Language, and Hearing Research*, *60*(7), 1843–1854. https://doi.org/10.1044/2016_JSLHR-S-16-0059

Holmqvist, S., Santtila, P., Lindström, E., Sala, E., & Simberg, S. (2013). The association between possible stress markers and vocal symptoms. *Journal of Voice*, *27*(6). https://doi.org/10.1016/j.jvoice.2013.06.012

Ilmarinen, J. (2009). Work ability—a comprehensive concept for occupational health research and prevention. In *Scandinavian Journal of Work, Environment & Health* (Vol. 35, Issue 1, pp. 1–5). https://doi.org/10.5271/sjweh.1304

Ilomäki, I. (2008). *Opettajien ääneen liittyvä työhyvinvointi ja äänikoulutuksen vaikutukset [Teachers' voice-related well-being at work and the effects of voice training.]* [Tampere University]. https://trepo.tuni.fi/bitstream/handle/10024/66411/978-951-44-7553-5.pdf?sequence=1&isAllowed=y

Ilomaki, I., Leppanen, K., Kleemola, L., Tyrmi, J., Laukkanen, A.-M., & Vilkman, E. (2009). Relationships between self-evaluations of voice and working conditions, background factors, and phoniatric findings in female teachers. *Logopedics Phoniatrics Vocology*, *34*(1), 20–31. https://doi.org/10.1080/14015430902856908

Ilomäki, I., Mäki, E., & Laukkanen, A.-M. (2005). Vocal symptoms among teachers with and without voice education. *Logopedics Phoniatrics Vocology*, *30*(3–4), 171–174. https://doi.org/10.1080/14015430500294106

Imhof, M., Välikoski, T.-R., Laukkanen, A.-M., & Orlob, K. (2014). Cognition and interpersonal communication: The effect of voice quality on information processing and person perception. *Studies in Communication Sciences*, *14*(1), 37–44. https://doi.org/10.1016/j.scoms.2014.03.011

Jääskelainen, A., Kausto, J., Seitsamo, J., Ojajarvi, A., Nygard, C.-H., Arjas, E., & Leino-Arjas, P. (2016). Work ability index and perceived work ability as predictors of disability pension: a prospective study among Finnish municipal employees. *Scandinavian Journal of Work, Environment & Health*, *42*(6), 490–499. https://doi.org/10.5271/sjweh.3598

Jacobson, B. H., Johnson, A., Grywalski, C., Silbergleit, A., Jacobson, G., Benninger, M. S., & Newman W., C. (1997). The Voice Handicap Index (VHI): development and validation. *American Journal of Speech-Language Pathology*, *6*(May 2016), 66–70.

Johnson, S., Cooper, C., Cartwright, S., Donald, I., Taylor, P., & Millet, C. (2005). The experience of work-related stress across occupations. *Journal of Managerial Psychology*, *20*(2), 178–187. https://doi.org/10.1108/02683940510579803

Jónsdóttir, V. (2003). *The Voice: An Occupational Tool. A Study of Teachers' Classroom Speech and the Effects of Amplification*. Tampere University Press. https://trepo.tuni.fi/handle/10024/67327

Kadakia, S., Carison, D., & Sataloff, R. T. (2013). The effects of hormones on the voice. *J Sing*, *69*, 571–574. http://www.vocapedia.info/_Library/JOS_files_Vocapedia/JOS-069-5-2013-571.pdf

Kagan, A., & Levi, L. (1974). Health and environment—Psychosocial stimuli: A review. *Social Science & Medicine (1967)*, *8*, 225–241. https://doi.org/10.1016/0037-7856(74)90092-4

Kallvik, E., Lindström, E., Holmqvist, S., Lindman, J., & Simberg, S. (2015). Prevalence of hoarseness in school-aged children. *Journal of Voice*, *29*(2), 260.e1-19. https://doi.org/10.1016/j.jvoice.2013.08.019

Kankare, E., Geneid, A., Laukkanen, A.-M., & Vilkman, E. (2012). Subjective Evaluation of Voice and Working Conditions and Phoniatric Examination in Kindergarten Teachers. *Folia Phoniatrica et Logopaedica*, *64*(1), 12–19. https://doi.org/10.1159/000328643

Karasek, R. A. (1979). Job Demands, Job Decision Latitude, and Mental Strain: Implications for Job Redesign. *Administrative Science Quarterly*, *24*(2), 285–308. http://www.jstor.org/stable/2392498

Karasek, R. A., Brisson, C., Kawakami, N., Houtman, I., Bongers, P., & Amick, B. (1998). The Job Content Questionnaire (JCQ): An instrument for internationally comparative assessments of psychosocial job characteristics. *Journal of Occupational Health Psychology*, *3*(4), 322–355. https://doi.org/10.1037/1076-8998.3.4.322

Karasek, R. A., & Theorell, T. (1990). Healthy Work: Stress, Productivity, and The Reconstruction Of Working Life. In *New York: Basic Books*.

Karjalainen, S., Brännström, J. K., Christensson, J., Sahlén, B., & Lyberg Åhlander, V. (2020). A Pilot Study on the Relationship between Primary-School Teachers' Well-Being and the Acoustics of their Classrooms. *International Journal of Environmental Research and Public Health*, *17*(6). https://doi.org/10.3390/ijerph17062083

Kauppinen, Timo; Mattila-Holappa, Pauliina; Perkiö-Mäkelä, Merja; Saalo, Anja; Toikkanen, Jouni; Tuomivaara, Seppo; Uuksulainen, Sanni; Viluksela, Marja; Virtanen, S. T. (2013). *Työ ja terveys Suomessa 2012*.

Klassen, R. M., & Chiu, M. M. (2011). The occupational commitment and intention to quit of practicing and pre-service teachers: Influence of self-efficacy, job stress, and teaching context. *Contemporary Educational Psychology*, *36*(2), 114–129. https://doi.org/10.1016/j.cedpsych.2011.01.002

Kooijman, P. G. C., de Jong, F. I. C. R. S., Thomas, G., Huinck, W., Donders, R., Graamans, K., & Schutte, H. K. (2006). Risk factors for voice problems in teachers. *Folia Phoniatrica et Logopaedica*, *58*(3), 159–174. https://doi.org/10.1159/000091730

Korhonen, E., Niemi, J., Ekuri, R., Oksa, R., Miettinen, H., Parviainen, J., Haapanen, A., & Patanen, T. (2018). *Kuntien rakennuskannan kehitys- ja säästöpotentiaali [Development and saving potential in the municipalities' building stock]*. Prime Minister's Office. https://tietokayttoon.fi/documents/10616/6354562/5-2018-Kuntien+rakennuskannan+kehitys-+ja+säästöpotentiaali.pdf/09dcb7ab-0e4a-43c4-aa08-1c393bcce686?version=1.0

Korn, G. P., Augusto de Lima Pontes, A., Abranches, D., & Augusto de Lima Pontes, P. (2015). Hoarseness and risk factors in university teachers. *Journal of Voice*, *29*(4), 518.e21-8. https://doi.org/10.1016/j.jvoice.2014.09.008

Kouvonen A, Oksanen T, Vahtera J, et al. (2016). *The Finnish Public Sector Study. A dataset of the basic report. 20170621.*

Kouvonen, A., Oksanen, T., Vahtera, J., Stafford, M., Wilkinson, R., Schneider, J., Väänänen, A., Virtanen, M., J. Cox, S., Pentti, J., Elovainio, M., & Kivimaki, M. (2018). *The Finnish Public Sector Study*. https://www.ttl.fi/tutkimushanke/kunta10-tutkimus/

Kristiansen, J., Lund, S. P., Persson, R., Shibuya, H., Nielsen, P. M., & Scholz, M. (2014). A study of classroom acoustics and school teachers??? noise exposure, voice load and speaking time during teaching, and the effects on vocal and mental fatigue development. *International Archives of Occupational and Environmental Health*, *87*(8), 851–860. https://doi.org/10.1007/s00420-014-0927-8

Kumpulainen, T. (Ed.). (2017). *Opettajat ja rehtorit Suomessa 2016 [Teachers and principals in Finland]*. Finnish National Agency for Education. http://www.oph.fi/julkaisut/2017/opettajat_ja_rehtorit_suomessa_2016

Kunnallinen yleinen virka- ja työehtosopimus KVTES [The General Collective Agreement]. (n.d.). https://www.kt.fi/sopimukset/kvtes/2020-2021

Kyriakou, C. (2001). Teacher Stress: Directions for future research. *Educational Review*, *53*, 27–35. https://doi.org/10.1080/00131910120033628

Kyriakou, C. (2011). Teacher stress: From prevalence to resilience. In J. Langan-Fox & C. L. Cooper (Eds.), *Handbook of stress in the occupations* (pp. 161–173). Edward Elgar Publishing Limited.

Lahtinen, M. (2004). Psychosocial work environment and indoor air problems: a questionnaire as a means of problem diagnosis. *Occupational and Environmental Medicine*, *61*(2), 143–149. https://doi.org/10.1136/oem.2002.005835

Lahtinen, Marjaana, Huuhtanen, P., Kähkönen, E., & Reijula, K. (2002). Psychosocial dimensions of solving an indoor air problem. *Indoor Air*, *12*(1), 33–46.

Lahtinen, Marjaana, Lappalainen, S., & Reijula, K. (2008). Multiprofessional teams resolving indoor-air problems: Emphasis on the psychosocial perspective. *Scandinavian Journal of Work, Environment & Health, Supplement*, *4*, 30–34.

Lahtinen, Marjaana, Salonen, H., Lappalainen, S., Huttunen, J., & Reijula, K. (2009). Renovation of a sick building: The challenge of attaining the confidence of occupants. *American Journal of Industrial Medicine*, *52*(5), 438–445. https://doi.org/10.1002/ajim.20678

Laukkanen, A.-M., Ilomaki, I., Leppanen, K., & Vilkman, E. (2008). Acoustic measures and self-reports of vocal fatigue by female teachers. *Journal of Voice*, *22*(3), 283–289. https://doi.org/10.1016/j.jvoice.2006.10.001

Lazarus, R. S. (1966). *Psychological stress and the coping process*. McGraw-Hill.

Levendoski, E. E., Leydon, C., & Thibeault, S. L. (2014). Vocal fold epithelial barrier in health and injury: a research review. *Journal of Speech, Language, and Hearing Research*, *57*(5), 1679–1691. https://doi.org/10.1044/2014_JSLHR-S-13-0283

Ley, P. (1972). *Quantitative aspects of psychological assessment*. Gerald Duckworth & Co. http://www.psychassessment.com.au/pdf/qapa.pdf

Lin, S., Lipton, E., Lu, Y., & Kielb, C. (2020). Are classroom thermal conditions, lighting, and acoustics related to teacher health symptoms? *Indoor Air*, *30*(3), 544–552. https://doi.org/10.1111/ina.12640

Loisel, P. (2009). Developing a new paradigm: Work disability prevention. *Occup Health Southern Africa*, *15*(Special ICOH Issue), 56–60.

Lundberg, U. (2005). Stress hormones in health and illness: The roles of work and gender. *Psychoneuroendocrinology*, *30*(10), 1017–1021. https://doi.org/10.1016/j.psyneuen.2005.03.014

Lundberg, U., Kadefors, R., Melin, B., Palmerud, G., Hassmen, P., Engstrom, M., & Dohns, I. E. (1994). Psychophysiological stress and EMG activity of the trapezius muscle. *International Journal of Behavioral Medicine*, *1*(4), 354–370. https://doi.org/10.1207/s15327558ijbm0104_5

Lyberg Åhlander, V., Haake, M., Brännström, J., Schötz, S., & Sahlén, B. (2015). Does the speaker's voice quality influence children's performance on a language comprehension test? *International Journal of Speech-Language Pathology*, *17*(1), 63–73. https://doi.org/10.3109/17549507.2014.898098

Lyberg Åhlander, V., Pelegrin Garcia, D., Whitling, S., Rydell, R., & Lofqvist, A. (2014). Teachers' voice use in teaching environments: a field study using ambulatory phonation monitor. *Journal of Voice*, *28*(6), 841.e5-15. https://doi.org/10.1016/j.jvoice.2014.03.006

Lyberg Åhlander, V., Rydell, R., Fredlund, P., Magnusson, C., & Wilén, S. (2019). Prevalence of Voice Disorders in the General Population, Based on the Stockholm Public Health Cohort. *Journal of Voice*, *33*(6), 900–905. https://doi.org/10.1016/j.jvoice.2018.07.007

Lyberg Åhlander, V., Rydell, R., & Löfqvist, A. (2011). Speaker's comfort in teaching environments: voice problems in Swedish teaching staff. *Journal of Voice*, *25*(4), 430–440. https://doi.org/10.1016/j.jvoice.2009.12.006

Lyberg Åhlander, V., Rydella, R., Löfqvista, A., Pelegrin-Garcíab, D., & Brunskogc, J. (2015). Teachers' voice use in teaching environment. Aspects on speakers' comfort. *Energy Procedia*, *78*, 3090 – 3095. https://doi.org/10.1016/j.egypro.2015.11.762

Ma, E. P.-M., & Yiu, E. M.-L. (2001). Voice activity and participation profile: assessing the impact of voice disorders on daily activities. *Journal of Speech, Language, and Hearing Research*, *44*(3, June), 511–524. https://doi.org/10.1044/1092-4388(2001/040)

Mäkelä, K., Hirvensalo, M., & Whipp, P. R. (2014). Should I Stay or Should I Go? Physical Education Teachers' Career Intentions. *Research Quarterly for Exercise and Sport*, *85*(2), 234–244. https://doi.org/10.1080/02701367.2014.893052

Manfreda, K. L., Bosnjak, M., Berzelak, J., Haas, I., & Vehovar, V. (2008). Web Surveys versus other Survey Modes: A Meta-Analysis Comparing Response Rates. *International Journal of Market Research*, *50*(1), 79–104. https://doi.org/10.1177/147078530805000107

Martins, R. H. G., Pereira, E. R. B. N., Hidalgo, C. B., & Tavares, E. L. M. (2014). Voice disorders in teachers. A review. *Journal of Voice*, *28*(6), 716–724. https://doi.org/10.1016/j.jvoice.2014.02.008

Mattiske, J. A., Oates, J. M., & Greenwood, K. M. (1998). Vocal problems among teachers: A review of prevalence, causes, prevention, and treatment. *Journal of Voice*, *12*(4), 489–499. https://doi.org/10.1016/S0892-1997(98)80058-1

McAleavy, G. J., Adamson, G., Hazlett, D. E., Donegan, H. A., & Livesey, G. E. (2008). Modelling determinants of the vocal health of teachers in Northern Ireland: implications for educational policy and practice. *Public Health*, *122*(7), 691–699. https://doi.org/10.1016/j.puhe.2007.08.013

McGonagle, A. K., Fisher, G. G., Barnes-Farrell, J. L., & Grosch, J. W. (2015). Individual and work factors related to perceived work ability and labor force outcomes. *The Journal of Applied Psychology*, *100*(2), 376–398. https://doi.org/10.1037/a0037974

McIntyre, T. M., McIntyre, S. E., & Francis, D. J. (Eds.). (2017). *Educator Stress: An Occupational Health Perspective.* Springer.

McNutt, L.-A., Wu, C., Xue, X., & Hafner, J. P. (2003). Estimating the relative risk in cohort studies and clinical trials of common outcomes. *American Journal of Epidemiology*, *157*(10), 940–943. https://doi.org/10.1093/aje/kwg074

Meklin, T., Putus, T., Pekkanen, J., Hyvärinen, A., Hirvonen, M., & Nevalainen, A. (2005). Effects of moisture-damage repairs on microbial exposure and symptoms in school children. *Indoor Air*, *15*(Suppl 10), 40–47.

Mendell, M. J., & Heath, G. A. (2005). Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air*, *15*(1), 27–52. https://doi.org/10.1111/j.1600-0668.2004.00320.x

Mendell, M. J., & Kumagai, K. (2017). Observation-based metrics for residential dampness and mold with dose-response relationships to health: a review. *Indoor Air*, *27*(3), 506–517. https://doi.org/10.1111/ina.12342

Mendell, M. J., Mirer, A. G., Cheung, K., Tong, M., & Douwes, J. (2011). Respiratory and allergic health effects of dampness, mold, and dampness-related agents: A review of the epidemiologic evidence. *Environmental Health Perspectives*, *119*(6), 748–756. https://doi.org/10.1289/ehp.1002410

Mendelson, M. B., Catano, V. M., & Kelloway, K. (2000). The role of stress and social support in Sick Building Syndrome. *Work & Stress*, *14*(2), 137–155. https://doi.org/10.1080/026783700750051658

Morton, V., & Watson, D. R. (2001). Voice in the classroom: A re-evaluation. In P. H. Dejonckere (Ed.), *Occupational Voice: Care and Cure* (pp. 53–69). Kugler Publications. http://ebookcentral.proquest.com/lib/kutu/detail.action?docID=309965.

Moy, F. M., Hoe, V. C. W., Hairi, N. N., Chu, A. H. Y., Bulgiba, A., & Koh, D. (2015). Determinants and Effects of Voice Disorders among Secondary School Teachers in Peninsular Malaysia Using a Validated Malay Version of VHI-10. *PLOS One*, *10*(11), e0141963. https://doi.org/10.1371/journal.pone.0141963

Munier, C., Brockmann-Bauser, M., Laukkanen, A.-M., Ilomäki, I., Kankare, E., & Geneid, A. (2020). Relationship Between Laryngeal Signs and Symptoms, Acoustic Measures, and Quality of Life in Finnish Primary and Kindergarten School Teachers. *Journal of Voice*, *34*(2), 259–271. https://doi.org/10.1016/j.jvoice.2018.12.006

Munier, C., & Kinsella, R. (2008). The prevalence and impact of voice problems in primary school teachers. *Occupational Medicine*, *58*(1), 74–76. https://doi.org/10.1093/occmed/kqm104

Murry, T., Medrado, R., Hogikyan, N. D., & Aviv, J. E. (2004). The relationship between ratings of voice quality and quality of life measures. *Journal of Voice*, *18*(2), 183–192. https://doi.org/10.1016/j.jvoice.2003.11.003

Naghieh, A., Montgomery, P., Bonell, C. P., Thompson, M., & Aber, J. L. (2015). Organisational interventions for improving wellbeing and reducing work-related stress in teachers. *The Cochrane Database of Systematic Reviews*, *4*, CD010306. https://doi.org/10.1002/14651858.CD010306.pub2

Nemr, K., Simões-Zenari, M., Almeida, V. C. de, Martins, G. A., & Saito, I. T. (2021). COVID-19 and the teacher’s voice: self-perception and contributions of speech therapy to voice and communication during the pandemic. *Clinics*, *76*. https://doi.org/10.6061/clinics/2021/e2641

Nerrière, E., Vercambre, M.-N., Gilbert, F., & Kovess-Masféty, V. (2009). Voice disorders and mental health in teachers: a cross-sectional nationwide study. *BMC Public Health*, *9*, 370. https://doi.org/10.1186/1471-2458-9-370

Núñez-Rodríguez, M. H., & Miranda Sivelo, A. (2008). Psychological Factors in Gastroesophageal Reflux Disease Measured by SCL-90-R Questionnaire. *Digestive Diseases and Sciences*, *53*(12), 3071–3075. https://doi.org/10.1007/s10620-008-0276-0

Nusseck, M., Spahn, C., Echternach, M., Immerz, A., & Richter, B. (2018). Vocal Health, Voice Self-concept and Quality of Life in German School Teachers. *Journal of Voice*, *34*(3), 488.e29-488.e39. https://doi.org/10.1016/j.jvoice.2018.11.008

Nybacka, I., Simberg, S., Santtila, P., Sala, E., & Sandnabba, N. K. (2012). Genetic and Environmental Effects on Vocal Symptoms and Their Intercorrelations. *Journal of Speech, Language, and Hearing Research*, *55*(2), 541. https://doi.org/10.1044/1092-4388(2011/10-0188)

Oakman, J., Neupane, S., Proper, K. I., Kinsman, N., & Nygard, C.-H. (2018). Workplace interventions to improve work ability: A systematic review and meta-analysis of their effectiveness. *Scandinavian Journal of Work, Environment & Health*, *44*(2), 134–146. https://doi.org/10.5271/sjweh.3685

OECD. (2018). *Education at a Glance 2018*. https://doi.org/10.1787/eag-2018-en

Ohlsson, A. C., Andersson, E. M., Södersten, M., Simberg, S., & Barregård, L. (2012). Prevalence of voice symptoms and risk factors in teacher students. *Journal of Voice*, *26*(5), 629–634. https://doi.org/10.1016/j.jvoice.2011.11.002

Ohlsson, A. C., Andersson, E. M., Södersten, M., Simberg, S., Claesson, S., & Barregård, L. (2015). Voice Disorders in Teacher Students—A Prospective Study and a Randomized Controlled Trial. *Journal of Voice*, *article in*(6), 755.e13-755.e24. https://doi.org/10.1016/j.jvoice.2015.09.004

Ozamiz-Etxebarria, N., Berasategi Santxo, N., Idoiaga Mondragon, N., & Dosil Santamaría, M. (2020). The Psychological State of Teachers During the COVID-19 Crisis: The Challenge of Returning to Face-to-Face Teaching. *Frontiers in Psychology*, *11*, 620718. https://doi.org/10.3389/fpsyg.2020.620718

Patel, R., & Schell, K. W. (2008). The influence of linguistic content on the Lombard effect. *Journal of Speech, Language, and Hearing Research*, *51*(1), 209–220. https://doi.org/10.1044/1092-4388(2008/016)

Patovirta, R. L., Husman, T., Haverinen, U., Vahteristo, M., Uitti, J., Tukiainen, H., & Nevalainen, A. (2004). The remediation of mold damaged school: A three-year follow-up study on teachers' health. *Central European Journal of Public Health*, *12*(1), 36–42.

Patovirta, R. L., Meklin, T., Nevalainen, A., & Husman, T. (2004). Effects of mould remediation on school teachers' health. *The International Journal of Environmental Health Research*, *14*(6), 415–427. https://doi.org/10.1080/09603120400012876

Pattyn, N., Migeotte, P.-F., Neyt, X., den Nest, A. van, & Cluydts, R. (2010). Comparing real-life and laboratory-induced stress reactivity on cardio-respiratory parameters: Differentiation of a tonic and a phasic component. *Physiology & Behavior*, *101*(2), 218–223. https://doi.org/10.1016/j.physbeh.2010.04.037

Payne, G., & Payne, J. (2004). *Key Concepts in Social Research*. https://doi.org/10.4135/9781849209397

Pekkarinen, E., Himberg, L., & Pentti, J. (1992). Prevalence of vocal symptoms among teachers compared with nurses: A questionnaire study. *Logopedics Phoniatrics Vocology*, *17*(2), 113–117. https://doi.org/10.3109/14015439209098721

Perryman, J., & Calvert, G. (2020). What motivates people to teach, and why do they leave? Accountability, performativity and teacher retention. *British Journal of Educational Studies*, *68*(1), 3–23. https://doi.org/10.1080/00071005.2019.1589417

Preciado-López, J., Pérez-Fernández, C., Calzada-Uriondo, M., & Preciado-Ruiz, P. (2008). Epidemiological Study of Voice Disorders Among Teaching Professionals of La Rioja, Spain. *Journal of Voice*, *22*(4), 489–508. https://doi.org/10.1016/j.jvoice.2006.11.008

Puglisi, G. E., Cutiva, L. C. C., Pavese, L., Castellana, A., Bona, M., & Fasolis, S. (2015). Acoustic comfort in high-school classrooms for students and teachers. *Energy Procedia*, *78*, 3096–3101. https://doi.org/10.1016/j.egypro.2015.11.763

Putus, T., Länsikallio, R., & Ilves, V. (2017). *Sisäilmatutkimus 2017*.

Putus, T., Vilén, L., & Atosuo, J. (2019). *Vantaan kaupungin sisäilmakysely päiväkotien, ala- ja yläkoulujen oppilaille, ammatti-instituutti Varian opiskelijoille sekä oppilaitosten henkilöstölle [City of Vantaa indoor air survey for kindergarten, primary and secondary school students, Varia vocat* (pp. 1–138). https://www.vanda.fi/instancedata/prime_product_julkaisu/vantaa/embeds/vantaawwwstructure/144442_Silmaoirekyselyn_loppuraportti_2019_Turun_yliopisto.pdf

Rantala, L. M., Hakala, S. J., Holmqvist, S., & Sala, E. (2012). Connections between voice ergonomic risk factors and voice symptoms, voice handicap, and respiratory tract diseases. *Journal of Voice*, *26*(6), 819.e13-819.e20. https://doi.org/10.1016/j.jvoice.2012.06.001

Rantala, L. M., & Sala, E. (2015). Associations between classroom conditions and teacher's voice production. *Energy Procedia*, *78*, 3120–3125. https://doi.org/10.1016/j.egypro.2015.11.767

Rantala, L. M., Sala, E., & Kankare, E. (2018). Teachers' Working Postures and Their Effects on the Voice. *Folia Phoniatrica et Logopaedica*, *70*(1), 24–36. https://doi.org/10.1159/000487593

Ravall, S., & Simberg, S. (2020). Voice Disorders and Voice Knowledge in Choir Singers. *Journal of Voice*, *34*(1), 157.e1-157.e8. https://doi.org/10.1016/j.jvoice.2018.07.005

Reijula, K., & Sundman-Digert, C. (2004). Assessment of indoor air problems at work with a questionnaire. *Occupational and Environmental Medicine*, *61*(1), 33–38. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1757823/

Rezende, B. A., Abreu, M. N. S., Assunção, A. Á., & de Medeiros, A. M. (2020). Factors Associated With the Limitation at Work Because of the Voice: Study With Teachers of Basic Education In Brazil. *Journal of Voice*. https://doi.org/10.1016/j.jvoice.2020.11.003

Richards, J. (2012). Teacher Stress and Coping Strategies: A National Snapshot. *The Educational Forum*, *76*(3), 299–316. https://doi.org/10.1080/00131725.2012.682837

Rimpelä, M., Rigoff, A.-M., Kuusela, J., & Peltonen, H. (Eds.). (2007). *Hyvinvoinnin ja terveyden edistäminen peruskouluissa [Promoting well-being and health in primary and secondary schools]*. The Finnish National Agency for Education.

Roy, N., Merrill, R., Thibeault, S., Gray, S., & Smith, E. (2004a). Voice disorders in teachers and the general population: effects on work performance, attendance, and future career choices. *J Speech Lang Hear Res*, *47*. https://doi.org/10.1044/1092-4388(2004/042)

Roy, N., Merrill, R., Thibeault, S., Parsa, R., Gray, S., & Smith, E. (2004b). Prevalence of Voice Disorders in Teachers and the General Population. *Journal of Speech, Language, and Hearing Research*, *47*(2), 281. https://doi.org/10.1044/1092-4388(2004/023)

Rudblad, S., Andersson, K., Stridh, G., Bodin, L., & Juto, J. E. (2002). Slowly decreasing mucosal hyperreactivity years after working in a school with moisture problems. *Indoor Air*, *12*(2), 138–144. https://doi.org/10.1034/j.1600-0668.2002.01112.x

Sakellaris, I. A., Saraga, D. E., Mandin, C., Roda, C., Fossati, S., De Kluizenaar, Y., Carrer, P., Dimitroulopoulou, S., Mihucz, V. G., Szigeti, T., Hänninen, O., De Oliveira Fernandes, E., Bartzis, J. G., & Bluyssen, P. M. (2016). Perceived Indoor Environment and Occupants' Comfort in European "Modern" Office Buildings: The OFFICAIR Study. *International Journal of Environmental Research and Public Health*, *13*(5). https://doi.org/10.3390/ijerph13050444

Sala, E., Hellgren, U., Ketola, R., Laine, A., Olkinuora, P., Rantala, L. M., & Sihvo, M. (2009). *Voice Ergonomic Assessment in Work Environment—Handbook and Checklist [in Finnish and Swedish].* The Finnish Institute of Occupational Health.

Sala, E., Laine, A., Simberg, S., Pentti, J., & Suonpää, J. (2001). The prevalence of voice disorders among day care center teachers compared with nurses: a questionnaire and clinical study. *Journal of Voice*, *15*(3), 413–423. https://doi.org///dx.doi.org/10.1016/S0892-1997(01)00042-X

Sala, E., & Rantala, L. M. (Eds.). (2019). *Voice Ergonomics: Occupational and Professional Voice Care*. Cambridge Scholars Publishing.

Sampaio, M. C., Borges dos Reis, E. J. F., Carvalho, F. M., Porto, L. A., & Araújo, T. M. (2012). Vocal Effort and Voice Handicap Among Teachers. *Journal of Voice*, *26*(6), 820.e15-820.e18. https://doi.org/10.1016/j.jvoice.2012.06.003

Santavirta, N., Solovieva, S., & Theorell, T. (2007). The association between job strain and emotional exhaustion in a cohort of 1,028 Finnish teachers. *The British Journal of Educational Psychology*, *77*(Pt 1), 213–228. https://doi.org/10.1348/000709905X92045

Sataloff, R. T. (2017). *Professional Voice: The Science and Art of Clinical Care* (Fourth edi). Plural Publishing, Inc.

Sataloff, R. T., Castell, D. O., Katz, P. O., Sataloff, D. M., & Hawkshaw, M. J. (2017). Reflux and Other Gastroenterologic Conditions That May Affect the Voice. In R. T. Sataloff (Ed.), *Professional Voice: The Science and Art of Clinical Care* (4th ed.). Plural Publishing, Inc.

Sauni, R., Uitti, J., Jauhiainen, M., Kreiss, K., Sigsgaard, T., & Verbeek, J. H. (2015). Remediating buildings damaged by dampness and mould for preventing or reducing respiratory tract symptoms, infections and asthma. *Cochrane Database of Systematic Reviews*, *9*, CD007897. https://doi.org/10.1002/14651858.CD007897.pub2

Savilahti, R., Uitti, J., & Husman, T. (2005). Validity and recall of information from questionnaires concerning respiratory infections among schoolchildren. *Central European Journal of Public Health*, *13*(2), 74–77.

Scheuch, K., Haufe, E., & Seibt, R. (2015). Teachers' Health. *Deutsches Arzteblatt International*, *112*(20), 347–356. https://doi.org/10.3238/arztebl.2015.0347

Schneider, G. T., Vaezi, M. F., & Francis, D. O. (2016). Reflux and Voice Disorders: Have We Established Causality? *Current Otorhinolaryngology Reports*, *4*(3), 157–167. https://doi.org/10.1007/s40136-016-0121-5

Schouteten, R. (2017). Predicting absenteeism: screening for work ability or burnout. *Occupational Medicine (Oxford, England)*, *67*(1), 52–57. https://doi.org/10.1093/occmed/kqw161

Sick leave absences in Finnish municipalities. (n.d.). Retrieved September 8, 2020, from https://tyoelamatieto.fi/#/fi/dashboards/kunta10-sick-leave

Simberg, S., Laine, A., Sala, E., & Rönnemaa, A.-M. (2000). Prevalence of voice disorders among future teachers. *Journal of Voice*, *14*. https://doi.org/10.1016/S0892-1997(00)80030-2

Simberg, S., & Sala, E. (2008). Experiences from five years of screening for voice disorders among teacher students. In A. Klippi & K. Launonen (Eds.), *Research in Logopedics: Speech and language therapy in Finland* (pp. 249–264). Multilingual Matters LTD.

Simberg, S., Sala, E., Laine, A., & Rönnemaa, A.-M. (2001). A fast and easy screening method for voice disorders among teacher students. *Logopedics Phoniatrics Vocology*, *26*(1), 10–16. https://doi.org/10.1080/14015430119481

Simberg, S., Sala, E., Tuomainen, J., & Rönnemaa, A. M. (2009a). Vocal Symptoms and Allergy: A Pilot Study. *Journal of Voice*, *23*(1), 136–139. https://doi.org/10.1016/j.jvoice.2007.03.010

Simberg, S., Sala, E., Tuomainen, J., Sellman, J., & Rönnemaa, A.-M. (2006). The effectiveness of group therapy for students with mild voice disorders: a controlled clinical trial. *Journal of Voice*, *20*(1), 97–109. https://doi.org/10.1016/j.jvoice.2005.01.002

Simberg, S., Sala, E., Vehmas, K., & Laine, A. (2005). Changes in the prevalence of vocal symptoms among teachers during a twelve-year period. *Journal of Voice*, *19*(1), 95–102. https://doi.org/10.1016/j.jvoice.2004.02.009

Simberg, S., Santtila, P., Soveri, A., Varjonen, M., Sala, E., & Sandnabba, N. K. (2009b). Exploring genetic and environmental effects in dysphonia: a twin study. *Journal of Speech, Language, and Hearing Research*, *52*(1), 153–163. https://doi.org/10.1044/1092-4388(2008/07-0095)

Sivasankar, M., Elizabeth, E., Sara, S., & Ashleigh, H. (2008). Phonatory Effects of Airway Dehydration: Preliminary Evidence for Impaired Compensation to Oral Breathing in Individuals

With a History of Vocal Fatigue. *Journal of Speech, Language, and Hearing Research*, *51*(6), 1494–1506. https://doi.org/10.1044/1092-4388(2008/07-0181)

Skaalvik, E. M., & Skaalvik, S. (2017). Teacher Stress and Teacher Self-Efficacy: Relations and Consequences. In T. M. McIntyre, S. E. McIntyre, & D. J. Francis (Eds.), *Educator Stress: An Occupational Health Perspective*. Springer International Publishing AG.

Sliwinska-Kowalska, M., Niebudek-Bogusz, E., Fiszer, M., Los-Spychalska, T., Kotylo, P., Sznurowska-Przygocka, B., & Modrzewska, M. (2006). The prevalence and risk factors for occupational voice disorders in teachers. *Folia Phoniatrica et Logopaedica*, *58*(2), 85–101. https://doi.org/10.1159/000089610

Śmiełowska, M., Marc, M., & Zabiegala, B. (2017). Indoor air quality in public utility environments - a review. *Environmental Science and Pollution Research International*, *24*(12), 11166–11176. https://doi.org/10.1007/s11356-017-8567-7

Smith, A., Johal, S., Wadsworth, E., Davey Smith, G., & Peters, T. (2000). *The scale of occupational stress: The Bristol Stress and Health at work study*. Health & Safety Executive.

Smith, E., Gray, S. D., Dove, H., Kirchner, L., & Heras, H. (1997). Frequency and effects of teachers' voice problems. *Journal of Voice*, *11*. https://doi.org/10.1016/S0892-1997(97)80027-6

Smith, E., Kirchner, H. L., Taylor, M., Hoffman, H., & Lemke, J. H. (1998a). Voice problems among teachers: Differences by gender and teaching characteristics. *Journal of Voice*, *12*(3), 328–334. https://doi.org/10.1016/S0892-1997(98)80022-2

Smith, E., Lemke, J., Taylor, M., Kirchner, H. L., & Hoffman, H. (1998b). Frequency of voice problems among teachers and other occupations. *Journal of Voice*, *12*(4), 480–488. https://doi.org/10.1016/S0892-1997(98)80057-X

Song, M.-K., Lin, F.-C., Ward, S. E., & Fine, J. P. (2013). Composite variables: when and how. *Nursing Research*, *62*(1), 45–49. https://doi.org/10.1097/NNR.0b013e3182741948

Soto, C. J., & John, O. P. (2017). Short and extra-short forms of the Big Five Inventory–2: The BFI-2-S and BFI-2-XS. *Journal of Research in Personality*, *68*, 69–81. https://doi.org/10.1016/j.jrp.2017.02.004

Spantideas, N., Bougea, A., Drosou, E., & Assimakopoulos, D. (2019). The Role of Allergy in Phonation. *Journal of Voice*, *33*(5), 811.e19-811.e27. https://doi.org/10.1016/j.jvoice.2018.02.016

Sukanen, O., Sihvo, M., Rorarius, E., Lehtihalmes, M., Autio, V., & Kleemola, L. (2007). Voice Activity and Participation Profile (VAPP) in assessing the effects of voice disorders on patients' quality of life: Validity and reliability of the Finnish version of VAPP. *Logopedics Phoniatrics Vocology*, *32*(1), 3–8. https://doi.org/10.1080/14015430600784386

Sumecki, D., Chipulu, M., & Ojiako, U. (2011). Email overload: Exploring the moderating role of the perception of email as a 'business critical' tool. *International Journal of Information Management*, *31*(5), 407–414. https://doi.org/10.1016/j.ijinfomgt.2010.12.008

Suomen tilastollinen vuosikirja 2020 [Statistical Yearbook of Finland 2020]. (2020). Statistics Finland. https://www.doria.fi/handle/10024/180368

Tähtinen, K., Lappalainen, S., Karvala, K., Remes, J., & Salonen, H. (2018). Association between four-level categorisation of indoor exposure and perceived indoor air quality. *International Journal of Environmental Research and Public Health*, *15*(4). https://doi.org/10.3390/ijerph15040679

Tähtinen, K., Remes, J., Karvala, K., Salmi, K., Lahtinen, M., & Reijula, K. (2020). Perceived indoor air quality and psychosocial work environment in office, school and health care environments in Finland. *International Journal of Occupational Medicine and Environmental Health*, *33*(4), 479–495. https://doi.org/10.13075/ijomeh.1896.01565

Talvensaari, O.-M. (2019). *Näyttelijäopiskelijoiden kokemat äänioireet ja stressin yhteys niihin [The voice symptoms experienced by actress students and the association with stress]*. University of Helsinki. https://helda.helsinki.fi/bitstream/handle/10138/306139/Talvensaari_Oona-Marleena_Pro_Gradu_2019.pdf?sequence=2&isAllowed=y

Tavares, E. L. M., & Martins, R. H. G. (2007). Vocal Evaluation in Teachers With or Without Symptoms. *Journal of Voice*, *21*(4), 407–414. https://doi.org/10.1016/j.jvoice.2006.04.001

Tengland, P.-A. (2011). The concept of work ability. *Journal of Occupational Rehabilitation*, *21*(2), 275–285. https://doi.org/10.1007/s10926-010-9269-x

Terveydenhuoltolaki 1326/2010 [Health Care Act]. (2010). Ministry of Social Affairs and Health, Finland. https://www.finlex.fi/fi/laki/ajantasa/2010/20101326#L2P16

Thach, T.-Q., Mahirah, D., Sauter, C., Roberts, A. C., Dunleavy, G., Nazeha, N., Rykov, Y., Zhang, Y., Christopoulos, G. I., Soh, C.-K., & Car, J. (2020). Associations of perceived indoor environmental quality with stress in the workplace. *Indoor Air*, *30*(6), 1166–1177. https://doi.org/10.1111/ina.12696

THL (The Finnish National Institute of Health and Welfare). (n.d.). *Benchmarking System of Health Promotion Capacity Building*. The Finnish National Institute of Health and Welfare (THL). Retrieved November 26, 2018, from https://teaviisari.fi/teaviisari/fi/tiedonkeruu/55

Thomas, G., Kooijman, P. G. C., Cremers, C. W. R. J., & de Jong, F. I. C. R. S. (2006). A comparative study of voice complaints and risk factors for voice complaints in female student teachers and practicing teachers early in their career. *European Archives of Oto-Rhino-Laryngology*, *263*(4), 370–380. https://doi.org/10.1007/s00405-005-1010-6

Thorsen, S. V., Pedersen, J., Flyvholm, M.-A., Kristiansen, J., Rugulies, R., & Bültmann, U. (2019). Perceived stress and sickness absence: a prospective study of 17,795 employees in Denmark. *International Archives of Occupational and Environmental Health*, *92*(6), 821–828. https://doi.org/10.1007/s00420-019-01420-9

Titze, I. R. (1989). Physiologic and acoustic differences between male and female voices. *The Journal of the Acoustical Society of America*, *85*(4), 1699–1707. https://doi.org/10.1121/1.397959

Titze, I. R., Lemke, J., & Montequin, D. (1997). Populations in the U.S. workforce who rely on voice as a primary tool of trade: a preliminary report. *Journal of Voice*, *11*. https://doi.org/10.1016/S0892-1997(97)80002-1

Travers, C. (2017). *Current Knowledge on the Nature, Prevalence, Sources and Potential Impact of Teacher Stress* (pp. 23–54). Springer International Publishing. https://doi.org/10.1007/978-3-319-53053-6_2

Trinite, B. (2016). Epidemiology of Voice Disorders in Latvian School Teachers. *Journal of Voice*, 1–9. https://doi.org/10.1016/j.jvoice.2016.10.014

Tuomi, K., Ilmarinen, J., Jahkola, M., Katajarinne, L., & Tulkki, A. (1997). *Työkykyindeksi [Work Ability Index]* (Työterveyshuolto 19). Finnish Institute of Occupational Health.

Tupakkalaki [Tobacco Act], Pub. L. No. 549 (2016). https://www.finlex.fi/fi/laki/alkup/2016/20160549

van Droogenbroeck, F., & Spruyt, B. (2015). Do teachers have worse mental health? Review of the existing comparative research and results from the Belgian Health Interview Survey. *Teaching and Teacher Education*, *51*(October), 88–100. https://doi.org/10.1016/j.tate.2015.06.006

van Houtte, E., Claeys, S., Wuyts, F., & Lierde, K. van. (2012). Voice disorders in teachers: occupational risk factors and psycho-emotional factors. *Logopedics Phoniatrics Vocology*, *37*, 107–116. https://doi.org/10.3109/14015439.2012.660499

van Houtte, E., Claeys, S., Wuyts, F., & Van Lierde, K. (2011). The impact of voice disorders among teachers: Vocal complaints, treatment-seeking behavior, knowledge of vocal care, and voice-related absenteeism. *Journal of Voice*, *25*(5), 570–575. https://doi.org/10.1016/j.jvoice.2010.04.008

Van Puyvelde, M., Neyt, X., McGlone, F., & Pattyn, N. (2018). Voice Stress Analysis: A New Framework for Voice and Effort in Human Performance. *Frontiers in Psychology*, *9*, 1994. https://doi.org/10.3389/fpsyg.2018.01994

Vedovato, T. G., & Monteiro, I. (2014). Health conditions and factors related to the work ability of teachers. *Industrial Health*, *52*(2), 121–128. https://doi.org/10.2486/indhealth.2013-0096

Verdolini, K., Titze, I. R., & Fennell, A. (1994). Dependence of Phonatory Effort on Hydration Level. *Journal of Speech, Language, and Hearing Research*, *37*(5), 1001–1007. https://doi.org/10.1044/jshr.3705.1001

Vertanen-Greis, H., Löyttyniemi, E., & Uitti, J. (2020a). Voice Disorders are Associated With Stress Among Teachers: A Cross-Sectional Study in Finland. *Journal of Voice*, *34*(3), 488.e1-488.e8. https://doi.org/10.1016/j.jvoice.2018.08.021

Vertanen-Greis, H., Löyttyniemi, E., Uitti, J., & Putus, T. (2021a). Self-reported Voice Disorders of Teachers and Indoor Air Quality in Schools: A Cross-Sectional Study in Finland. *Logopedics Phoniatrics Vocology*, Jul 28: 1-11. Epub ahead of print. https://doi.org/10.1080/14015439.2021.1953132

Vertanen-Greis, H., Löyttyniemi, E., Uitti, J., & Putus, T. (n.d.-b). The Interaction between Stress at Work and Voice Disorders for Work Ability of Teachers. *Submitted to Journal of Preventive Medicine and Hygiene*.

Vertanen-Greis, H., Löyttyniemi, E., Uitti, J., & Putus, T. (2020b). Work ability of teachers associated with voice disorders, stress, and the indoor environment: A questionnaire study in Finland. *Journal of Voice*, *Oct 8;S089*. Online ahead of print. https://doi.org/10.1016/j.jvoice.2020.09.022

Vertanen-Greis, H., Löyttyniemi, E., Uitti, J., & Putus, T. (2021b). *Dataset of the dissertation (n = 1 198), Mendeley Data, V1*. https://doi.org/10.17632/j27j94my79.1

Vertanen-Greis, H., Löyttyniemi, E., Uitti, J., & Putus, T. (2021c). *Dataset of the school buildings, Mendeley Data, V1*. https://doi.org/10.17632/tgknj4yz6f.2

Vilkman, E. (2004). Occupational safety and health aspects of voice and speech professions. *Folia Phoniatrica et Logopaedica*, *56*(4), 220–253. https://doi.org/10.1159/000078344

Vintturi, J., Alku, P., Lauri, E. R., Sala, E., Sihvo, M., & Vilkman, I. (2001). Objective analysis of vocal warm-up with special reference to ergonomic factors. *Journal of Voice*, *15*(1), 36–53. https://doi.org/10.1016/s0892-1997(01)00005-4

Virtanen, A., De Bloom, J., & Kinnunen, U. (2020). Relationships between recovery experiences and well-being among younger and older teachers. *International Archives of Occupational and Environmental Health*, *93*(2), 213–227. https://doi.org/10.1007/s00420-019-01475-8

Vlemincx, E., Taelman, J., De Peuter, S., Van Diest, I., & Van Den Bergh, O. (2011). Sigh rate and respiratory variability during mental load and sustained attention. *Psychophysiology*, *48*(1), 117–120. https://doi.org/10.1111/j.1469-8986.2010.01043.x

von Leden, H. (2017). A Cultural history of the larynx and Voice. In R. T. Sataloff (Ed.), *Professional Voice: The Science and Art of Clinical Care* (4th ed.). Plural Publishing, Inc.

Vuokko, A., Selinheimo, S., Sainio, M., Suojalehto, H., Järnefelt, H., Virtanen, M., Kallio, E., Hublin, C., & Karvala, K. (2015). Decreased work ability associated to indoor air problems: An intervention (RCT) to promote health behavior. *NeuroToxicology*, *49*, 59–67. https://doi.org/10.1016/j.neuro.2015.04.010

Wargocki, P., Porras-Salazar, J., Contreras, S., & Bahnfleth, W. (2020). The relationships between classroom air quality and children's performance in school. *Building and Environment*, 106749. https://doi.org/10.1016/j.buildenv.2020.106749

WHO (World Health Organization) guidelines for indoor air quality: dampness and mould. (2009). http://www.euro.who.int/__data/assets/pdf_file/0017/43325/E92645.pdf?ua=1

WHO International Classification of Functioning, Disability and Health. (2001). World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/42407/9241545429_tha+eng.pdf

Witt, R. E., Taylor, L. N., Regner, M. F., & Jiang, J. J. (2011). Effects of surface dehydration on mucosal wave amplitude and frequency in excised canine larynges. *Otolaryngology—Head and Neck Surgery*, *144*(1), 108–113. https://doi.org/10.1177/0194599810390893

Wolkoff, P. (2018a). The mystery of dry indoor air: An overview. *Environment International*, *121*(October), 1058–1065. https://doi.org/10.1016/j.envint.2018.10.053

Wolkoff, P. (2018b). Indoor air humidity, air quality, and health: An overview. *International Journal of Hygiene and Environmental Health*, *221*(3), 376–390. https://doi.org/10.1016/j.ijheh.2018.01.015

Work Smarter: An End to Burnout Britain: The case for sensible regulation to tame the modern workplace. (2000). London: TUC Campaigns and Communication Department.

Yiu, E. M.-L., & Chan, R. M. M. (2003). Effect of Hydration and Vocal Rest on the Vocal Fatigue in Amateur Karaoke Singers. *Journal of Voice*, *17*(2), 216–227. https://doi.org/10.1016/S0892-1997(03)00038-9

Zenger, A. (2019). *Validation of a fast and easy screening method for voice disorders*. http://www.doria.fi/handle/10024/167721

TURUN
YLIOPISTO
UNIVERSITY
OF TURKU

Painosalama, Turku, Finland 2021

ISBN 978-951-29-8501-2 (PRINT)
ISBN 978-951-29-8502-9 (PDF)
ISSN 0355-9483 (Print)
ISSN 2343-3213 (Online)