VOICE ERGONOMICS
- AN OVERVIEW OF RECENT RESEARCH

Södersten, M[1] and Lindhe, C[2]
[1]Department of Logopedics and Phoniatrics, CLINTEC, Karolinska Institute, Karolinska university hospital, Huddinge, SE-141 86 Stockholm, Sweden. E-mail: maria.Södersten@ki.se
[2]Röstkonsult, Lilla Grevegårdsvägen 29, SE-426 55 Göteborg, Sweden. christina.lindhe@rostkonsult.se

The area of voice disorders includes voice ergonomics, i.e., awareness of work-related risk factors for voice disorders, knowledge about how to improve voice production and speech intelligibility in different work environments to prevent occupational voice disorders. The purpose of this paper is to give an overview of research within the area in which several research groups in the Nordic countries are active. Results are presented from different perspectives such as prevalence, clinical, field, experimental and intervention studies. Increased knowledge about voice ergonomics will make demands on diagnostics and intervention for patients with occupational voice disorders in the future.

Key word: voice ergonomics, occupational voice, vocal loading, voice disorders, voice accumulator, voice dosimetry,

1. Introduction

Approximately one third of the total labor force is working in professions in which voice use is an essential, if not crucial, part of their work (Vilkman, 2004). Professional voice users can be classified as *instructors/teachers* (school teachers, pre-school teachers, fitness instructors), *performers* (broadcasters, actors, singers), *persuasive voice users* (politicians, lawyers, ministers, auctioneers, salespeople including telemarketers), *service voice users* (counselors, operators, customer service assistants) and professions within *emergency* (police, fire department, emergency medical technicians, air traffic controllers).

Potential environmental risk factors have been identified for a number of these vocally demanding professions e.g., extensive voice use without enough time for voice rest, to speak in high background noise, poor room acoustics, poor indoor air quality, poor speaking postures, and lack of appropriate technical aid such as voice amplifiers. These loading factors can also be called " ..vocoergonomic factors.." (Vilkman, 2004, p.239).

Voice professionals who are referred to medical clinics are most often diagnosed with phonastenia (vocal fatigue), dysphonia or vocal nodules. Common voice symptoms of these diagnoses are vocal fatigue and hoarseness, symptoms that increase with extensive voice use. The importance of occupational safety and health arrangement regarding voice ergonomics is now being recognized in relationship to guidelines and legislations created for occupational safety and health systems in different countries (Dejonckere, 2002, pp. 129-137). In Sweden, Arbetsmiljöverket has recommendations on noise levels (AFS 2005:16, pp.18, 27) and stresses the potential risk for vocal loading, especially for women, when speaking in noisy environments (ibid, pp.18-19).

Voice ergonomics may be defined as awareness of work-related risk factors for voice disorders and knowledge about how to improve voice production and speech intelligibility in different working environments with the goal to prevent occupational voice disorders (Sala et al., 2005). The purpose of this paper is to give an overview of recent research within the area of voice ergonomics in which several research groups in the Nordic countries are very active.

2. Prevalence of voice disorders and consequences

Until recently there have been few epidemiological studies of the prevalence of voice disorders in the general population. A cross-sectional telephone survey with a random sample of 1.326 adults, ranging in age from 20 to 66 years, was conducted in the U.S. by Roy et al. (2005). Questions were addressed within three areas related to voice disorders: prevalence, potential risk factors and occupational consequences/effects. In the study the definition of a voice disorder was "any time the voice does not work, perform or sound as it normally should, so that it interferes with communication" (ibid. p. 1989). It was found that 29.9 % of the participants had had a voice disorder during their lives and 6.6% reported a voice disorder at the time of the survey. The authors also identified factors that increased the risk for voice disorders i.e., gender (women), age (40-59 years), voice use patterns and vocal demands (to talk for a long period, talk quietly, talk loudly), chemical exposure, and frequent cold/sinus infections. Of the participants, 4.3 % were limited or unable to do certain tasks at work because of voice problems, 7.2% reported one or more days of voice-related absence from work, and 2% reported being absent from the work more than 4 days as a consequence of the voice disorder (Roy et al., 2005). In an earlier study, with a similar design, Roy et al. (2004) found from interviews with 1.243 teachers, that 58% had had a voice disorder earlier in their lives and as much as 11% reported a voice disorder at the time of the survey. A number of studies have also shown a high prevalence of voice disorders among teachers as compared to e.g., nurses (e.g., Ohlsson, 1988; Pekkarinen et al., 1992; Smith et al., 1987). A recent study conducted in Finland reported an increase of voice symptoms in teachers during a 12-year period (Simberg et al., 2005).

3. Clinical studies - voice disorders and occupation

The percentage of professional voice users among the working population in the U.S. was identified by Titze et al. (1997). The definition of professional voice users were "…(a) those who depend on a consistent, special or appealing voice quality as a primary tool of trade, and (b) those, who, if afflicted with dysphonia or aphonia, would generally be discouraged in their jobs and seek alternative employment, …"(ibid., p. 254). The largest group was those who had sales related occupations (13 %), and the second largest group was teachers (4.2%). Furthermore Titze et al. (1997) compared the percentage of different occupations in voice clinics to that in the working population. A special group within sales was telephone marketers who comprised 2.3% of the clinical load as compared to 0.8% of the population which is a ratio of about 3:1, indicating a disproportion. Teachers made up 19.6% of the patients as compared to 4.2 % of the population, also a high ratio (4.5:1). Singers comprised 11.5% of the clinical load and 0.02% of the population and thus showed the largest disproportion with a ratio of 575:1.

Teachers were the most common occupational group in voice clinics in Sweden based on data from 1.212 patients with diagnosed voice disorders (Fritzell, 1996). Teachers comprised 16% of the patients and 5.9 % of the working population at the

time of the study. This ratio of about 3:1 was interpreted as if teachers were overrepresented in the voice clinic. Other common occupational groups in Sweden were office workers, people in social and health work, sales persons and clerical work. The most common diagnoses among the patients were phonastenia (vocal fatigue) and vocal nodules. Women were in the majority of those diagnosis groups, 72% and 97% respectively (Fritzell, 1996). Women are especially at risk for occupational voice disorders, as compared to men, one reason being anatomical and morphological differences in the larynx (Dejonckere, 2002, pp.11-22).

4. Field studies – voice use during work

Several methods have been developed over the years to document the amount of voice use during work. In Ohlsson's doctoral dissertation about voice and working environment from 1988 she found e.g., that male welders had more strained voices as compared to a control group based on measurements of fundamental frequency (F0) and voice intensity (sound pressure level or SPL). The values of F0 and SPL were significantly higher for the welders probably due to the exposure of high background noise. The welders also reported a significantly higher degree of vocal symptoms. Using long time average spectra (LTAS) and phonetogram (the minimum and maximum range of voice intensity and fundamental frequency) voices of switchboard operators were analyzed as being more breathy and less sonorous after a working day as compared to a control group (Ohlsson, 1988).

Vocal behaviour of teachers and pre-school teachers has been documented during working hours by a voice accumulator to measure fundamental frequency and phonation time, using a microphone attached to the larynx (Ohlsson, 1988; Szabo, 2004). Phonation time is the accumulated time that the vocal folds vibrate, and is about 30% during a working day for teachers (Rantala, Vilkman, 1999). Using more advanced technology, portable voice dosimeters have been further developed to measure vocal loading (Titze et al., 2003; Cheyne et al., 2003). There are on-going studies of a large number of teachers who are recorded with the dosimeter for several days and weeks both at work and leisure time. Parameters used to measure different vocal doses are: *time dose* (total phonation time, measured in seconds), *cycle dose* (the total number of vocal fold vibrations) and *distance dose* (the total distance the vocal folds are moving measured in meters). Common values from cycle dose measurements are 1 ½ - 2 million vocal fold vibrations during a working day for a female teacher (Titze et al., 2003).

Speaking in background noise is a well-known risk factor for vocal strain. It is therefore important to document the level of background noise and the speaker's voice simultaneously. A portable binaural DAT-recorder was used in ten pre-schools, while the teachers voices and the background noise were recorded during all activities all through a working day. The recordings were then analysed to separate the voice from the background noise (Södersten et al., 2002). Among the results, the pre-school teachers raised both voice intensity and fundamental frequency significantly during a working day as compared to normal conversation in a silent room. The background noise levels were found to be in average 76 dBL_{eq} for the ten pre-schools (range 73-79) which is very high for verbal communication. A level of 55 dB is desired so that the speaker does not have to raise the voice level (AFS 2005:16).

Dust and dry air on stage may induce symptoms from the respiratory and vocal tract in singers and actors which may affect their vocal performance (Richter et al.,

2000). Climatic considerations have been described and humidification units were found to improve temperature, humidity and fine dust concentration in theatre environments. Prophylactic intervention, such as steam inhalation and fluid intake, were suggested when unacceptable performance environments were found. Also toxic substances have been identified at an opera stage (Richter et al., 2002). A causal link was suggested between the toxic substances and the patients' voice symptoms i.e., hoarseness, respiratory tract irritation and biological findings, i.e., inflammatory mucous membrane of the mouth, larynx and throat and reduction in the mucosal wave during vocal fold vibrations.

5. Experimental studies of vocal loading

A number of experimental studies have been conducted by a voice research team in Finland. Different body postures (standing vs. sitting), varied degree of air humidity (low vs. high), and speaking with different voice intensity (low vs. high) were compared and analysed using acoustic and aerodynamic methods in vocally healthy men and women. Among the complex results it was found that vocal loading led to a more hyperfunctional vocal behavior in women as compared to men (for an overview of the studies, see Vilkman, 2004).

Studies on vocal loading, e.g., loud speech during exposure of realistic background noise have showed that vocally healthy women use lower sound intensity (in dB SPL), higher fundamental frequency (in Hz) and higher values of phonation time as compared to men when they tried to make themselves heard amidst the background noise (Södersten et al., 2005; Ternström et al., 2002; 2006). Furthermore, the women found it more difficult to make themselves heard during the noise exposure and experienced a higher degree of vocal effort (Södersten et al., 2005).

Experimental studies on hydration and voice production have showed that a dehydration condition increase the phonation threshold pressure (PTP) since it is believed that dehydration reduces the viscosity in the vocal folds. This was confirmed in the study since it became more difficult to phonate softly, especially for women, as compared to phonation during a hydration condition (Verdolini-Marston et al., 1994; Verdolini et al., 2002).

Mendoza and Carballo (in Dejonckere, 2002) studied the effect of induced stress on voice production and assumed that a stressful environment would cause an increase in the tension of the vocal muscles, leading to a higher and more tense voice. The results showed that a stressful environment and cognitive loading tasks affected the voice characteristics e.g., the fundamental frequency increased as compared to baseline data.

6. Intervention studies – voice amplification and voice training

Voice amplifiers in classrooms have been recommended for teachers so that they do not have to raise voice intensity to be heard (Vilkman, 2004). Sapienza et al. (1999) found that the mean sound pressure level (SPL) decreased for ten vocally healthy female teachers when they used amplifiers resulting in less phonatory effort. A series of studies have been conducted in Iceland both with portabel and stationary amplification systems (Jonsdottir, 2002). Among the results, F0 and SPL decreased which reduced the vocal loading for the teachers when they used amplification. They also found it more comfortable to speak. In a study of three male and two female teachers, the subjects reported that it was easier to speak and rated reduced vocal symptoms i.e., vocal fatigue

when they used the amplification. Furthermore, the teachers did not need to repeat the instructions as much, the concentration and collaboration in the classroom was positively affected, and the pupils reported that they heard the teacher better (Jonsdottir et al., 2001). A negative finding was frustration if the technical system did not work. A prerequisite for good technical amplification is optimal room acoustics for speaking (Jonsdottir, 2002).

Another important way of intervention is voice training. A screening test has been developed in Finland to find teacher students at risk for voice problems that require medical care and/or voice training (Simberg, 2004). Teacher students were divided at random into a voice training group and a control group. Results showed that voice training given in groups had long-term positive effects at the one-year follow-up. The teacher students' subjective vocal symptoms had decreased significantly, as compared to the control group (Simberg et al., 2006). Lehto et al. (2005) showed a positive long-term effect (1 year follow-up) after a two days vocal training course for 35 female and 10 male call-center customer advisers. The female subjects reduced their vocal strain and hoarseness after the course while the male subjects reported increased vocal symptoms after the training and at the follow up. Bovo et al. (in press) found positive effects of a short vocal training course for 21 female teachers, also at a one-year follow-up. In comparison with a control group, the subjects reported improved vocal behaviour and their voices showed positive changes when perceptually and acoustically evaluated. The scores of VHI (Voice Handicap Index) also decreased.

7. Future clinical work

The increased knowledge of voice ergonomics and risk factors in the work environment will affect and develop the clinical work regarding diagnostics and intervention for patients with occupational voice disorders in the future. For example, there is a need for voice clinicians to visit patients in their work environment to make systematic observations of voice ergonomic factors. Recommendations how to improve the work environment can be made based on those observations as well as to adapt the voice therapy to the patient's specific needs. There is also a need for documentation of patients' voices during work e g., using voice accumulators. However, the technical equipments e.g., voice accumulators and voice dosimeters are mainly used within research projects and are still not available for clinical purposes and routines. There is a need for studies including larger subject groups within the research areas described in this paper. Especially intervention studies with randomized controlled design are needed within the area of voice ergonomics.

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