

# Vocal Behavior in Environmental Noise: Comparisons Between Work and Leisure Conditions in Women With Work-related Voice Disorders and Matched Controls

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**Summary: Objectives.** This study aimed to assess vocal behavior in women with voice-intensive occupations to investigate differences between patients and controls and between work and leisure conditions with environmental noise level as an experimental factor.

**Methods.** Patients with work-related voice disorders, 10 with phonasthenia and 10 with vocal nodules, were matched regarding age, profession, and workplace with 20 vocally healthy colleagues. The sound pressure level of environmental noise and the speakers' voice, fundamental frequency, and phonation ratio were registered from morning to night during 1 week with a voice accumulator. Voice data were assessed in low ( $\leq 55$  dBA), moderate, and high ( $>70$  dBA) environmental noise levels.

**Results.** The average environmental noise level was significantly higher during the work condition for patients with vocal nodules (73.9 dBA) and their controls (73.0 dBA) compared with patients with phonasthenia (68.3 dBA) and their controls (67.1 dBA). The average voice level and the fundamental frequency were also significantly higher during work for the patients with vocal nodules and their controls. During the leisure condition, there were no significant differences in average noise and voice level nor fundamental frequency between the groups. The patients with vocal nodules and their controls spent significantly more time and used their voices significantly more in high-environmental noise levels.

**Conclusions.** High noise levels during work and demands from the occupation impact vocal behavior. Thus, assessment of voice ergonomics should be part of the work environmental management. To reduce environmental noise levels is important to improve voice ergonomic conditions in communication-intensive and vocally demanding workplaces.

**Key Words:** Long-term voice accumulation–Vocal loading–Occupational Voice disorders–Work environment management.

## INTRODUCTION

Excessive noise interferes with people's daily activities at work, school, home, and during periods of leisure, and may also influence vocal behavior if a person needs to speak during the noise.<sup>1,2</sup> According to a report from the World Health Organization, noise pollution is not only an environmental nuisance but is also a threat to public health.<sup>3</sup> Noise can impair hearing, disturb sleep, cause stress and hypertension, affect cardiovascular functions and psychophysiology, reduce performance, and provoke irritation and changes in social behavior.<sup>4</sup> It is recognized in a report from the European Agency for Safety and Health at Work<sup>5</sup> that there is a lack of research on the effects of occupational noise exposure on health in nonindustrial and communication-demanding workplaces, for example, within education, health care, customer call centers, and offices, where there is often a

high proportion of employed women. Generally, compared to male-dominated industrial workplaces, women appear to be more exposed to medium levels of noise.<sup>5</sup> In such workplaces, it is not the stationary noise levels that disturb the most, but the occasional high levels of environmental noise caused by the activity, for example, children's play and screaming in nurseries and schools, or voices and other sounds from people in open office spaces. This so-called activity noise may have a negative impact on speech communication and interferes with performance and well-being, which has been reported from the school environment,<sup>6–10</sup> offices,<sup>11,12</sup> and hospital wards.<sup>13</sup> It has been acknowledged that a high proportion of women in communication-demanding work sectors, such as within education and health care, report noise-induced hearing-related symptoms and tinnitus.<sup>5,14,15</sup> A substantial proportion also suffers from voice disorders.<sup>5</sup>

The impact of environmental noise on vocal behavior and vocal health is relatively unexplored. Most studies have been conducted in the laboratory and not in field environments. Extensive voice use during high levels of environmental noise can cause voice symptoms<sup>16</sup> and has been mentioned as a risk factor for developing voice disorders.<sup>17–20</sup> It is believed that the vocal fold tissue may be harmed because of the elevated vibration forces when the speaker has to increase vocal loudness to be heard in the noise.<sup>21,22</sup> Excessive noise levels around and above 70 dBA are common in many communication and vocally demanding workplaces such as schools and preschools,<sup>9,23–25</sup> and can lead to negative consequences for vocal health.<sup>26</sup> In Finland, for

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example, vocal nodules have been reported to be six times more frequent in preschool teachers than in nurses,<sup>27</sup> and 10% of the teachers in another Finnish study had vocal nodules.<sup>28</sup> In the study by Sala et al,<sup>27</sup> 50% of the preschool teachers reported at least two voice symptoms weekly vs 27% of the nurses. The correlation between noisy working conditions and voice problems has been reported also for other professions, such as call center personnel.<sup>29</sup>

In a public health survey in Sweden, 16.9% of an open cohort of 114,538 adults, with a response rate of 64.9%, reported voice problems that were not due to colds and upper airway infections (15.5% reported that their voice problems occurred to a small extent and 1.4% reported that their voice problems occurred to a great extent). Women reported voice problems to a significantly larger extent than men.<sup>30</sup> In another Swedish study, 13% of the teachers experienced voice problems sometimes, often, or always.<sup>31</sup> Women with voice-intensive occupations are at an especially high risk of developing functional voice disorders such as phonasthenia and vocal nodules.<sup>32</sup> In the study by Fritzell,<sup>32</sup> 33% of the patient load ( $N = 1212$ ) in a voice clinic had phonasthenia and 16% had vocal nodules. Furthermore, 72% of the patients with phonasthenia and 97% of the patients with vocal nodules were women. Vocal nodules were more frequent in women with voice-intensive occupations. According to Vilkmán,<sup>18</sup> a voice disorder can be considered work-related when the voice is affected in such way that it does not meet the vocal demands that the work requires.

The causes and effects of work-related voice disorders are multifaceted. They include work-related and individual risk factors and coping strategies, as well as genetics.<sup>18,33,34</sup> It seems that environmental factors have a stronger impact on the development of voice disorders than do genetic factors,<sup>35,36</sup> although there is no clear understanding why some individuals are more prone than others to developing a voice disorder, despite similar working conditions and vocal loads.<sup>18,37</sup> It has been assumed that functional-organic voice disorders such as vocal nodules are caused by vocal overuse, for example, extensive voice use with few opportunities for voice rest in combination with high levels of voice sound pressure level (SPL) or speaking fundamental frequency ( $f_0$ ).<sup>38–40</sup> However, according to results from a recent study, the relationships between actual measures of daily or habitual voice use and phonotrauma, such as vocal nodules and polyps, are unclear and need to be further investigated.<sup>37</sup>

To enhance the audibility of the voice in loud environmental noise, the speaker typically increases the voice SPL, which concomitantly increases  $f_0$  and may result in hyperfunction.<sup>22,41–45</sup> Noise levels for conversation should be kept below 50–55 dBA to maintain speech intelligibility.<sup>22</sup> Below 55 dBA, a speaker does not need to increase voice SPL to be heard. At 70 dBA, the speaker needs to increase the voice SPL, and at 80–85 dBA, the speaker must shout to be heard at 1 m.<sup>46</sup> These observations were made on vocally healthy speakers. In the case of pathologic voices, speakers may find it even harder to be heard over lower environmental noise levels. For example, in an American questionnaire study, as many as 65% of patients with voice disorders reported difficulties in making themselves heard in noisy environments.<sup>47</sup> Furthermore, it seems that women experience

more strain to make themselves heard in noise compared with men.<sup>44</sup>

There are microprocessor-based portable systems for registration of voice use in daily life situations, the so-called voice accumulators of different designs,<sup>48–51</sup> and earlier there were portable digital audio tape recorders.<sup>52,53</sup> Voice accumulators have been developed to measure  $f_0$ , phonation time (ie, the time during which the vocal folds are vibrating), and voice SPL. Those data can be the basis for different vocal dose measures such as time dose (phonation time), cycle dose (number of oscillatory cycles), and distance dose.<sup>21,54</sup> Voice accumulators provide continuous long-term registration for several weeks. *VoxLog* (Sonvox AB, Umeå, Sweden) is one of the more recent devices and the only one that also measures the level of the environmental noise.<sup>55–57</sup> Long-term monitoring of vocal behavior has been conducted on individuals with voice-intensive occupations, in particular, teachers and call center employees.<sup>24,58–64</sup>

Although some studies exist, more knowledge is needed about the vocal behavior of individuals who need to speak in high background and activity noise levels in daily life.<sup>1,2,65,66</sup> The number of clinical studies monitoring voice use in patients with voice disorders is increasing but still few.<sup>16,37,67–71</sup> Therefore, patients with work-related voice disorders were the target group of the present study, with the focus on vocal behavior in relation to noise in real-life settings.

The aim of this exploratory study was to assess vocal behavior in female participants with voice-intensive occupations to compare voice use in patients with work-related voice disorders vs vocally healthy controls, and during work vs leisure conditions with environmental noise level as an experimental factor. One hypothesis was that voice use differs between patients and vocally healthy controls, so that the patients either speak more and louder, and use higher  $f_0$  than the controls, or speak less to rest and conserve their voices because of their voice disorder. We also assumed that vocal load is higher during work than during leisure, and that voice SPL and  $f_0$  increase in high-environmental noise levels.

## METHODS

### Participants

Forty women with voice-intensive occupations participated in the study (Table 1 and Figure 1). Twenty were patients with diagnosed voice disorders and 20 were vocally healthy controls. Of the total number of patients, 10 had phonasthenia and 10 had vocal nodules. Phonasthenia was defined as a functional voice disorder with normal laryngeal status and vocal fatigue as the predominant symptom.<sup>32</sup> Phonasthenia refers also to various symptoms of discomfort in and around the throat, strain, difficulties in projecting the voice and being heard in noisy environments, often resulting in an inability to meet vocal demands in a vocally demanding occupation. Vocal nodules were defined as benign bilateral epithelial swellings of the vocal folds, which are thought to arise after prolonged mechanical friction on the vocal fold mucosa.<sup>38,72</sup> Common voice symptoms are hoarseness and strain, and the voice often sounds breathy, hyperfunctional, hoarse, rough, and unstable.<sup>73</sup> Because work-related voice disorders are more

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