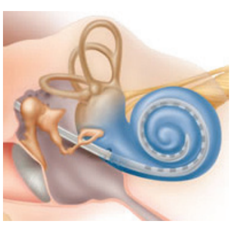
Original Article

Vestibular Symptoms in Factory Workers Subjected to Noise for a Long Period

G Raghunath, LB Suting, S Maruthy

Department of Audiology, All India Institute of Speech and Hearing, Manasagangotri (Mysore University Campus), Mysore, India



Abstract

Background: Noise can cause permanent or temporary hearing loss. High levels of noise may stimulate the vestibular system and thereby cause disturbances in the balancing mechanism.

Objective: To determine the effect of long-term exposure to occupational noise on the vestibular system.

Methods: A dizziness questionnaire was administered to 20 factory workers who were exposed to occupational noise for more than 10 years. The results were compared with 2 control groups. The control group 1 consisted of 20 people who had similar physical activity during work but were not exposed to high level of noise. Control group 2 consisted of 20 students never exposed to hazardous noise.

Results: There was significant difference between the experimental group and the 2 control groups in terms of frequency of vestibular symptoms. However, most of the symptoms were subtle in nature. Tinnitus was significantly ($p<0.05$) more frequent in the experimental group than the 2 control groups.

Conclusions: Long-term exposure to noise may cause vestibular symptoms before clinically detectable hearing loss. The symptoms are subtle for which they are mostly neglected; the symptoms do not affect the functional ability of workers.

Keywords: Hearing loss, noise-induced; Vestibular diseases; Dizziness; Vertigo; Hair cells, auditory

Introduction

Noise is defined as "unwanted sound" with various deleterious effects on health. The most significant physiological effect of exposure to noise is either temporary or permanent hearing loss.[1-4] Unfortunately, noise-induced hearing loss (NIHL) is so common that a majority of the workers believe that it is part of their normal working life course. This is especially disturbing considering that NIHL is nearly always preventable. It has been estimated that 1.1 million people are exposed to excessive noise at work; among these, 0.17 million are predicted to suffer significant ear damage as a direct result of noise.[5] Furthermore, noise can delay sleep and shift the sleep stages upward.[6] It can also cause annoyance and subsequently lead to several psychological perturbations that can

Correspondence to Sandeep Maruthy, Department of Audiology, All India Institute of Speech and Hearing, Manasagangotri (Mysore University Campus), Mysore, India
E-mail: msandeepa@gmail.com

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seriously affect the quality of life of not only the individuals affected but also their relatives.[7] Many workers including those engaged in heavy industry, factories, forge hammering, coal and ore mining, construction, cement plants, gas processing industry and mechanical engineering as well as mill and stationary machine device operators and workers at oil refineries are at risk of developing occupational NIHL.[8]

The vestibular portion of the auditory system helps in maintaining balance in association with the ocular and the central nervous system. The vestibular end organs and the cochlea have a common evolutionary origin and utilize the same basic principle of mechano-electric transduction with the help of the sensory hair cells.[9] The studies on vestibular evoked myogenic potential have shown that saccule can be stimulated with sound levels at or above 100 dB SPL.[10,11] Considering this, the levels of noise that can cause damage to the cochlea could also stimulate the balance system. Moreover, the saccule has been reported to withstand much lesser force (0.57 gf/mm) than the Reissener's membrane (0.84 gf/mm) meaning that with similar stimulations, the probability of the balance system being affected due to noise is more than that of cochlea.

Unlike the situation with hearing, noise is not usually considered a common etiology of dizziness, vertigo or other vestibular disturbances. The tuning frequency range in cochlear hair cells is different from that of vestibular hair cells. While cochlear hair cells are tuned to respond to frequencies between almost 20 Hz and 20 kHz, the vestibular hair cells are better responded to frequencies between 0 and 10 Hz.[8] Nevertheless, the conditions under which noise induces cochlear damage is very similar to that it causes vestibular damage.[12-14]

Animal studies showed pathologic evidence of damage in the utricle, saccule, and the semicircular canals, after exposure to intense noise.[15-18] There is also a striking resemblance between the damage patterns observed in the cochlea and vestibular structures.[15] Two mechanisms are involved in the destruction of the vestibular end organs by noise: direct mechanical destruction, and metabolic decompensation with subsequent degeneration of sensory elements.[17] Therefore, it is likely that individuals who have NIHL in addition to cochlear lesion, will have damage to the vestibular end organs too.[18]

In 1886, Barr reported that individuals exposed to noise had a sensation of "giddiness." Urbantschitsch demonstrated that nystagmus can be induced in humans by auditory stimuli.[19] Tullio (1929 cited in Kwee[20]) could activate the vestibular system through auditory stimulation to one of the ears, the so-called "Tullio phenomenon."

There are few studies reported in literature showing the vestibular disturbances in individuals with NIHL.[13,14,21,22] Those with NIHL are reported to have significantly increased body sway,[23,24] higher incidence of nystagmus,[13] reduced vestibular evoked potential,[25] lower vestibulo-ocular reflex gain and decreased caloric responses[12] compared to those without occupational noise exposure. The severity of these vestibular symptoms is more in asymmetrical hearing loss and it does not correlate with the extent of hearing loss.[26] However, all of these studies assessed vestibular function in individuals with known NIHL; therefore, although it is clear that vestibular end organs are dysfunctional in individuals with NIHL, it is not clear if these dysfunctions can occur prior to cochlear damage.

Most countries in the world recognize the compensation offered to the factory workers. Vestibular symptoms such as

For more information on occupational noise-induced hearing loss see www.theijoem.com/ijoem/index.php/ijoem/article/view/36

TAKE-HOME MESSAGE

- Prolonged exposure to high level of occupational noise does influence the vestibular system negatively.
- The resulting symptoms are subtle in nature and are not affecting daily activities to a great extent.
- One needs to seriously attend to the issue while deciding on the medico-legal issues like compensation.

vertigo and other balance problems affect an individual's daily activities to a great extent (compared to hearing loss) and those with vestibular disturbances may be disabled. These problems should be treated as early as possible. There is well documented evidence for vestibular dysfunction in people with NIHL, but there are no attempts made to study the vestibular symptoms in those who although are exposed to occupational noise, do not have NIHL. We therefore conducted the present study to determine the effect of long-term exposure to occupational noise on the vestibular system and to understand the vestibular function in those who although are exposed to occupational noise, do not have NIHL.

Patients and Methods

Subjects

The study involved three groups of people—one experimental and two control groups. The experimental group consisted of 20 weavers aged between 18 and 32 years. They were exposed to occupational noise for more than 10 years. The work schedule was eight hours a day, six days a week, and one hour lunch break. The work involved physical activity in the standing position. The "equivalent continuous noise level" (L_{eq}) of occupational noise averaged over 10 minutes was 108 dB SPL. The sound level meter (SLM) was kept at the position of a representative weaver during his work. Subjects in both the control groups worked in an environment where the noise levels were well within the damage risk criteria of 90 dB(A). The control group 1 consisted of 20 people who worked as waiters in a busy restaurant who also had eight hours a day, six days a week and one hour lunch break work schedule. Their work predominantly required a vertical posture similar to weavers. However, the L_{eq} averaged over 10 minutes was 69 dB SPL at a representative point in the restaurant. Control group 2 consisted of 20 graduate and post-graduate students of audiology. None of them were exposed to hazardous noise at any point of their life, as they themselves reported. All the participants were randomly selected from those who were willing to participate in this study.

Subjects in all the three groups had normal hearing sensitivity (hearing thresholds within 15 dB HL) between 250 Hz and 8000 Hz as assessed on a pure tone audiometry tested using a calibrated Orbiter 922. They had normal middle ear function as on immittance evaluation tested using a calibrated GSI Tympstar. 'A' type tympanogram with normal acoustic reflex thresholds, as defined by Jerger,[27] ensured normal middle ear function. Transient-evoked otoacoustic emissions (TEOAEs) were also measured (using ILO 292 Echoport plus) for participants in the three study groups. None of the participants reported of any past or present history of relevant neurological dysfunctions. Pure tone audiometry, immittance evaluation and TEOAEs were carried out prior to the administration of questionnaire, on the same day. All tests were done on Sundays which was an off day for their work.

Instruments

Questions related to the individual's work environment and its effects on dizziness were the highlights of the present questionnaire. The other questions in the study were compiled using the following questionnaires:

- UC Irvine Dizziness Questionnaire[28]
- Psychometric properties of the vertigo symptom scale[29]
- Dizziness questionnaire[30] developed by Maryland Hearing and Balance Center, University of Maryland Medical Center, Baltimore, MD

The final questionnaire (Appendix I) had six sections:

- Symptoms that define dizziness
- Chronology
- Details regarding the severity of dizziness with respect to the work environment
- Otological problems
- General health and habits
- Vertigo functional level scale

The questions in the first section included symptoms that a person with peripheral vestibular disorders such as benign paroxysmal positional vertigo, Meniere's disease, superior semicircular canal dehiscence, and vestibular neuritis would present with and can be considered without any doubt as vestibular symptoms. Selection was done in such a way that the final questionnaire included questions to study subtle as well as strong symptoms.

The questions in the second section were asked only from those who exhibited vestibular symptoms. Those questions would furnish details regarding the nature and onset of dizziness and also the frequency of dizziness attacks.

Questions in the third section pertained to the severity of dizziness in the participants' work environments and about the variation in the severity of symptoms between working and non-working hours.

Section four tried to study the otological conditions of these people. Questions regarding hearing sensitivity and tinnitus were included in this section.

The questions in section five helped us decide if dizziness occurred due to chronic alcoholism, chain smoking or any of the factors mentioned.

Section six has choices that are a gradation of severity of the dizziness and its effect on the individual's functional capacity.

The questionnaire was given to six experts in the field of vestibular assessment who found it had face validity.

For more information on the questionnaire (Appendix I) see the article's *Web-extra* on our Web site.

Test Administration

The final questionnaire was administered to all the three study groups—one experimental group and two control groups. The original questionnaire was in English, but these questions were translated to Kannada and Tamil (regional languages spoken in South India). The correct translation was ensured through back-translation, done by 10 native speakers who knew English, but were blinded to the purpose of the study. The reliability of the questionnaire was measured by test-retest. In 15 individuals in the experimental group, the questionnaire was re-administered after 20 days. Results showed a Cronbach's alpha of 0.83 reflecting a good reliability.

The time taken to administer the questionnaire was around 4–5 minutes for each participant. Written informed consent was taken from the participants and the participants did not have any objection to participate in the research study.

The symptoms reported by the subjects were further grouped into two types, based on the severity of the symptom. The grouping of the symptoms was done by ten masters students of speech and hearing, who rated the symptoms of the dizziness from their own experience by alternative forced binary choice method, *i.e.*, they were given only two choices—"subtle" symptoms and "strong" symptoms.

Results

The mean TEOAEs had lower amplitude in the experimental group (6.9 dB SPL) compared to the control group 1 (14.8 dB SPL) and control group 2 (14.3 dB SPL).

There were six sections in the questionnaire. Therefore, the results of the present study are reported for each of those sections separately.

Presence of Vestibular Symptoms

The questionnaire studied the presence/absence of eight symptoms that may be present in an individual with vestibular disorders. Table 1 shows comparison of the total number of participants with positive vestibular symptoms across the three groups. Those symptoms which were rated as subtle were more prevalent than those rated as strong (Table 1).

Chronology

All of the seven participants who had vestibular symptoms, reported that dizziness came in attacks. The average duration of exposure to noise for these participants was 21 years; they reported that dizziness occurred twice a week and it lasted for 5–10 seconds. They also reported that conditions like profuse sweating and increased heart rate served as warning signs. Most of the participants described the first episode of dizziness as light headedness, nausea and black-outs.

General Pattern

All the seven participants with vestibular symptoms reported that the severity of dizziness increased by the end of day; the dizziness was relatively relieved during non-working hours, while it became worse by overwork or exertion. During an attack, all the seven participants reported that 5–10 minutes of rest generally relieved the symptoms and helped them re-

Table 1: The frequency distribution of symptoms among the studied groups

Symptom	Experimental Group (n=20)	Control Group 1 (n=20)	Control Group 2 (n=20)
Light headedness	16[a]	6[b]	10[b]
Sensation that you are turning*	3[a]	0[a]	0[a]
Sensation that things are turning around you*	3[a]	0[a]	0[a]
Unable to stand or walk properly without support, veering or staggering to one side*	9[a]	2[b]	2[b]
Headache	16[a]	6[b]	8[b]
Pressure in the head	17[a]	4[a]	4[a]
Nausea or vomiting	5[a]	0[b]	0[b]
Feeling faint, about to black out*	6[a]	1[b]	3[a,b]

In each row, numbers with different superscripts are significantly different ($p<0.05$).
*These symptoms were rated by 9 of 10 judges as "strong"; others symptoms were rated as "subtle."

turn to work.

Presence of Otological Symptoms

We found a higher prevalence of tinnitus compared to hearing loss (Fig 1). There prevalence of tinnitus in the experimental group was significantly ($p<0.05$) higher than that in the control groups (Fig 1); there was no significant difference between the two control groups.

General Health and Habits

Figure 2 shows the frequency distribution of alcohol abuse and smoking in the three studied groups.

Vertigo Functional Level Scale

Three of the seven participants with vestibular symptoms reported that the dizziness passed quite quickly and they could resume their activities; the other four reported that it took relatively longer for the dizziness to pass.

Discussion

We found that the likelihood of developing vestibular symptoms was significantly higher in the experimental group compared to those in the control group 2—those who had not been exposed to hazardous noise. The higher prevalence of vestibular symptoms in the experimental group could be due to two reasons—exposure to noise and physical activity. To rule out the effect of physical activity on dizziness, control group 1 was studied; they had similar physical activity in their work environment as that of the experimental group. There was a significant difference in the frequency of tinnitus between these two groups (Fig 1). We therefore, concluded that occurrence of dizziness in these factory workers does not attributed to their physical activity and the symptoms are probably due to long-term exposure to noise.

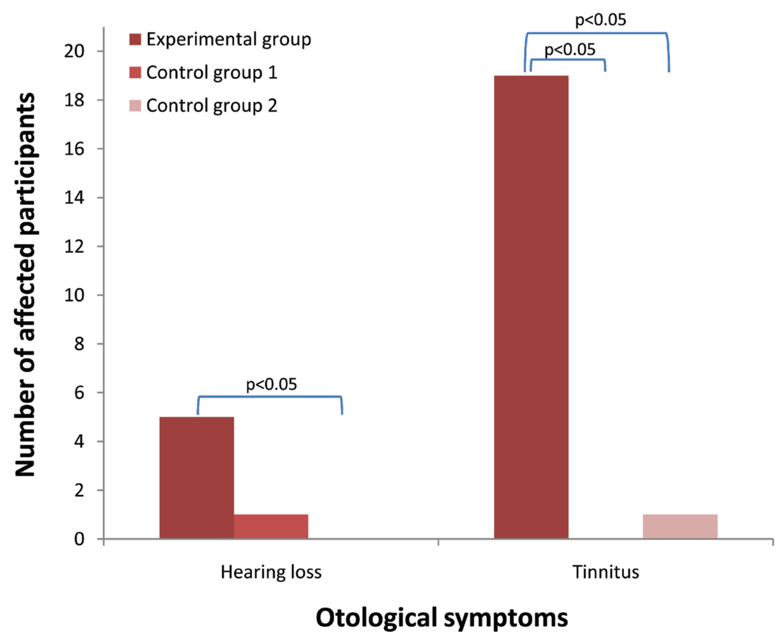

Figure 1: Frequency distribution of hearing loss and tinnitus in the three studied groups

There was significant differences in the prevalence of vestibular symptoms in the studied groups (Table 1). The observed differences were probably due to the difference in the severity of these symptoms. The subtle symptoms were more prevalent than the strong symptoms. Subtlety of the symptoms could be the reason for vestibular problems being usually neglected or going unnoticed. However, one should be aware that the severity of the symptoms may not be an accurate measure of the extent of damage to the vestibular structures. The balance function is controlled by cerebellum and the cortical structures apart from vestibular structures. In instances of vestibular end organ damage, the compensatory strategies may be adopted by the central nervous system. Therefore, there is a real need to thoroughly examine the signs and symptoms presented by factory workers while taking history and clinical examination.

Another finding of this study was the increased severity of the symptoms dur-

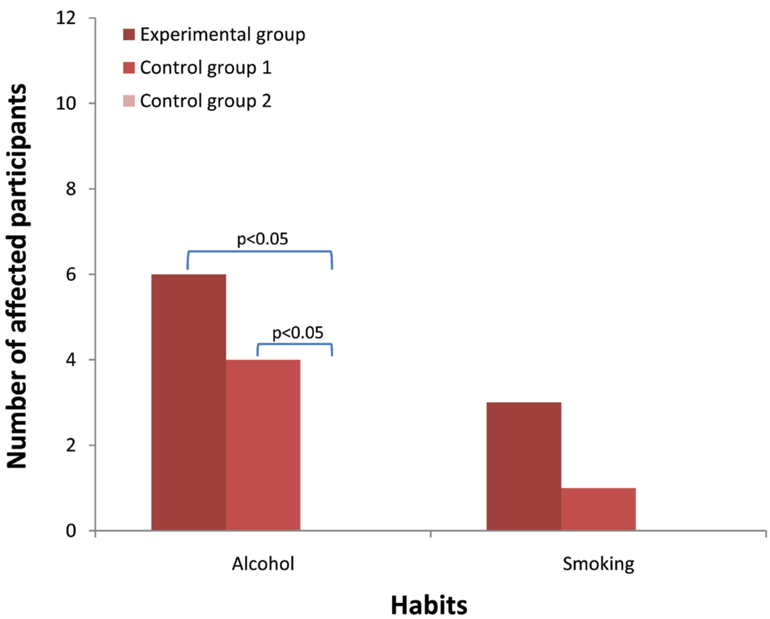

Figure 2: Frequency distribution of alcohol abuse and smoking in the three studied groups

ing the work in the experimental group—within a day, as the exposure to noise increased, there was an increase in severity of dizziness. This is another supporting factor indicating that noise is the cause of dizziness in these workers. Another factor supporting the hypothesis is that in most instances reduced hearing sensitivity and tinnitus are positively correlated. Coexistence of vestibular and otological symptoms strongly indicates that the vestibular and cochlear structures are gradually degenerating together due to chronic exposure to noise.

Chronic alcoholism and chain-smoking were potential confounding variables that could affect the study as they could cause dizziness independently of noise exposure. There rate of alcohol consumption was not significantly differenct between the experimental group and the control group 1 (Fig 2). Of the 20 workers in the experimental group, six consumed alcohol which is not unusual; they were not chronic alcoholics. The same holds true for smoking. Thus, we concluded that these factors were not the main causes of dizziness in the experimental group, and chronic exposure to noise was again the main etiology for the dizziness.

Dizziness was reported to occur in attacks and lasted for a short period. Therefore, the vestibular deficits were subtle and they did not substantially affect the individual's functional capability.

Another important finding was that the vestibular deficits were prevalent prior to clinically evident hearing loss. Although one-fourth of these individuals had reported hearing loss while answering the questionnaire, all of them had normal hearing on pure tone audiometry. Perception of hearing loss in those people was probably due to the damage to the central auditory processes. However, this is only a hypothesis and needs to be experimentally investigated.

In the present study, we also found that the weavers had reduced TEOAEs compared to the control groups, indicating damage to their outer hair cells. This was true despite a normal pure tone thresholds. This would be an evidence to subclinical damage of the outer hair cells that may not be evident on a pure tone audiometry. This finding is in agreement with earlier studies.[31-33]

Three conclusions can be drawn from the present study: vestibular symptoms exhibited by factory workers can be owed to the constant onslaught of noise on the ears of these workers; the symptoms exhibited by these workers are subtle due to which vestibular symptoms are neglected; and these symptoms do not affect their functional ability. Therefore, it is recommended that every person who reports history of exposure to occupational noise, is asked to complete a questionnaire such as the one used in the present study and investigated for vestibular symptoms.

Two important aspects should be considered while interpreting the results of the present study: first, the individuals who reported hearing loss were few in number and therefore, they can be labelled as industrial workers with occupational noise exposure and thus, the results cannot be generalized to those with a significant degree of NIHL. Second, the study is done only on 20 workers from a single factory and therefore, information on sensitivity and specificity of the questionnaire cannot be well authenticated.

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Conflicts of Interest: None declared.

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