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Prevention of noise induced hearing loss in worker: A literature review

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ABSTRACT

Noise induced hearing loss (NIHL) is a hearing loss due to noise that exceeds the hearing threshold limit value (TLV) in a work environment. Impacts of this disorder are decreased concentration, fatigue, headaches, sleep disturbances, and loss of job. Therefore, it is very important for industry stakeholders and workers to understand about the NIHL, so they can prevent and rehabilitate this problem. Risk factors that affect degrees of severity of deafness are noise intensity, frequency, duration of exposure per day, length of work, individual sensitivity, age and other factors that can cause deafness. Based on this, it can be understood that an amount of received exposure of noise energy will be similarly proportional as obtained damage. In general, NIHL cannot be cured but can be prevented and rehabilitated. Its prevention can be by applying hearing conservation program (HCP) such as noise measurement procedure, noise control, periodic audiometry measurement, hearing protection, worker education, recording, and evaluation. Some of benefits that can be obtained from the hearing conservation program are as a guide to diagnose hearing loss to prevent health impacts from noise exposure.

Gangguan pendengaran akibat bising (noise induced hearing loss/NIHL) adalah penurunan pendengaran atau tuli akibat bising yang melebihi nilai ambang batas (NAB) dengar di lingkungan kerja. Dampak dari gangguan ini adalah kurangnya konsentrasi, kelelahan, sakit kepala, gangguan tidur, hingga berdampak kepada kehilangan pekerjaan. Oleh karena itu sangatlah penting bagi pelaku industri maupun pekerja memahami tentang NIHL sehingga dapat melakukan upaya pencegahan dan rehabilitasi untuk mengatasi permasalahan ini. Faktor resiko yang berpengaruh pada derajat parahnya ketulian ialah intesitas bising, frekuensi, lama pajanan perhari, masa kerja, kepekaan individu, umur dan faktor lain yang dapat menimbulkan ketulian berdasarkan hal tersebut dapat dimengerti bahwa jumlah pajanan energi bising yang diterima akan sebanding dengan kerusakan yang didapat. Secara umum NIHL memang tidak dapat disembuhkan namun dapat dicegah dan dilakukan rehabilitasi. Pencegahan dapat dilaksanakan dengan cara penerapan hearing conservation program (HCP) yaitu dengan prosedur pengukuran kebisingan, pengendalian kebisingan, pengukuran audiometri berkala, perlindungan pendengaran, pendidikan pekerja, pencatatan dan evaluasi. Beberapa manfaat yang dapat diperoleh dari HCP adalah sebagai pedoman untuk mendiagnosis hearing loss, pencegahan terhadap dampak perburukan akan terpapar kebisingan.

INTRODUCTION

Hearing loss has long been recognized as an occupational disease.[1,2] The most severe impact of a noisy work environment is permanent deafness which is known as noise induced hearing loss (NIHL).[3,4] Globally, hearing loss in the United States 16% occurs in adults and 78.1% of hearing loss in industrial workers in

Malaysia is due to a noisy work environment.[1,3,5,6] NIHL is decreased hearing or deafness caused by noise that exceeds the threshold value (TLV).[1,6] NIHL is generally used to indicate that high accumulative exposure of noise over months or years can contributes for permanent hearing loss.[7] Continued exposure to high noise levels can cause gradual hearing loss for a period of 6-10 years.[1,8]

Chronic occupational noise can contribute to hearing loss, hypoacusis, auricular profusion, earaches, and tinnitus.[2,3,7,8] Tinnitus is one of signs of hearing loss, and it usually occurs in 2% of a population of industrialized countries. Hearing loss due to noise has occurred for a long time. Research conducted in 2010 in Makassar conducted in three factories with different noise sources stated that hearing loss occurred in 95 people (35%) of the total employees.[1] According to the National Committee for the Control of Hearing Loss and Deafness in 2014, The incidence of hearing loss due to noise in Indonesia is 36 million people or 16.8% of the total population, this figure is among the highest in Southeast Asia.[9] Works that are identified at high risk of exposure to noise and can have a hearing loss is work in mining, wood products manufacturing, construction and housing. in mining, wood product manufacturing, building construction and housing. Although a company provides a range of hearing protection devices, their high prevalence may indicate poor adherence to their use.[2,4,10]

In a study, it was also found that some noise sources exceeding the TLV set by a company can cause an increase of the hearing threshold of some employees by by 5-10 decibels (5-10 dB), or it can increase to 25 dB or more.[1,3] Noise exposure can coexist with other causative agents that may interact with it. Noise will give effect to the hearing, including exposure to certain chemicals, vibration, use of some medications, and individual susceptibility.[7] Hearing loss caused by noise is the second most common form of sensorineural hearing deficit after presbycusis (age-related hearing loss).[4,11]

Industrial noise has long been a problem that has not been resolved properly so that it can become a serious threat to workers' hearing, as it can cause permanent hearing loss. Meanwhile, for industry, noise can cause economic losses due to compensation costs.[1] Therefore, it is necessary to monitor some factories and check the hearing of their workers periodically.[1,2,7] Aims of this literature study is to prevent the incidence of NIHL in workers.

METHODS

ScienceDirect, ResearchGate, and Google Scholar databases from 2013 to 2020. The author limits the year of publication to collect recent research results. The literature review was also traced according to the characteristics of NIHL prevention and control in workers as well as exposure to pathophysiology and its risk factors.

Inclusion criteria used in searching the literatures were in the following: Health research or related articles published in a period 2013-2020, research articles covering topics on NIHL (epidemiology, pathophysiology, risk factors) and research articles covering topics on NIHL prevention and control. Based on the collected literatures from the several databases, there were 15 articles that met the inclusion criteria. Furthermore, these 15 articles were further reviewed to observe more detailed ways of preventing NIHL in a work environment.

RESULTS

In general, noise is unwanted sound. Noise with an intensity of 85 dB or higher than 85 dB can cause damage to corti hearing receptors in the inner ear.[1,8,9] Normal hearing can receive sound conveyed to the ear properly. A hearing process is generated by sound waves of different speed and volume. Sound waves travel through the outer ear cavity causing a tympanic membrane to vibrate. These vibrations are transmitted to the incus and stapes through the malleus associated with the tymphani membrane. The bone vibrates and causes the vibration to be magnified and transmitted to

the vestibular phenestra to the perilymph. The vibrations are then transferred through the tymphani membrane to the endolymph in the cochlear tract, and the stimulation reaches the nerve endings in the cortiary organs and is conveyed to the brain.[4]

With increasing intensity and duration of exposure, more damage will be found such as loss of stereocilia.[12] The first area affected is the basal area. With the loss of stereocilia, hair cells die and are replaced by scar tissue. The higher the intensity of the sound exposure, the more the damage of deep hair cells and supporting cells. As the damage to the hair cells becomes more widespread, degeneration of nerves can occur, which can also be found in the auditory nucleus of the brain stem. Hearing loss due to continuous noise exposure must be distinguished from acoustic trauma. Acoustic traumatic hearing loss is caused by short (one-time) direct exposure followed by permanent hearing loss. Its sound stimulation intensity generally exceeds 140 dB and often lasts <0.2 seconds. Acoustic trauma can cause teared tympanic membrane tear and cell wall disruption so that it is mixed with perilymph and endolymph. Acoustic trauma can also cause ossicular injury.[12]

Occupational hearing loss (noise induced hearing loss) is a permanent loss of a part or all of a person's hearing, affecting one or both ears due to continuous noise in a workplace. This disturbance occurs gradually and over a long period of time, so that workers are not aware.[9] Main characteristics of the occupational NIHL devided into four.[13] NIHL is always sensorineural, mainly affecting cochlear hair cells in the inner ear. NIHL is usually bilateral as the most noise exposure affects both ears symmetrically. NIHL has either unilateral or bilateral symptoms, usually affecting higher frequencies (3 kHz, 4 kHz or 6 kHz) and then spreading to lower frequencies (0.5 kHz, 1 kHz or 2 kHz).[11,12] The first sign is the “notching'' of the audiogram at a high frequency of 3000 Hz, 4000 Hz or 6000 Hz with recovery at 8000 Hz.

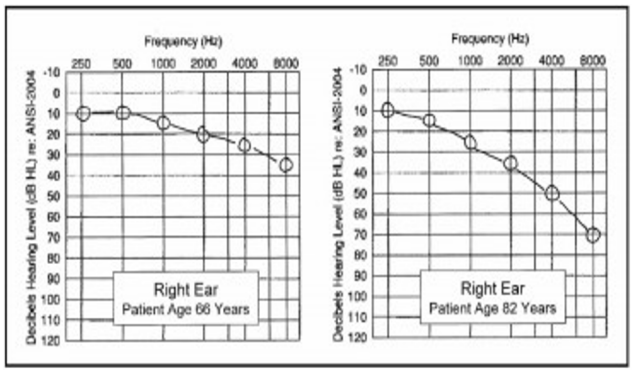

Figure 1. Audiogram of presbycusis

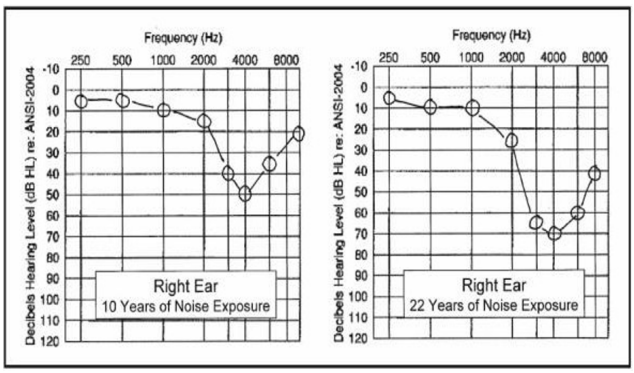

Figure 2. Audiogram of Noise Induced Hearing Loss (NIHL)

A worker's hearing function is identified by pure tone audiometric examination. An audiogram that drops at a frequency of 4000 Hz but improves at 8000 Hz indicates NIHL. Then if it continues to decline without improvement, it is presbycusis. Hearing loss due to continuous or intermittent noise exposure increases most rapidly during the first 10 to 15 years of exposure, and the rate of hearing loss then decreases as the hearing threshold increases. This is contrast to age-related losses, which accelerate over time. Noise exposure itself usually does cause a hearing loss of more than 75 dB at high frequencies and greater than 40 dB at low frequencies. However, individuals with non-NIHL, such as presbycusis have hearing threshold levels that exceed these values.[14] There is an insufficient evidence to conclude that hearing loss due to noise will continue after noise exposure has stopped. NIHL risks increase with long-term noise exposure above 80 dB and increases significantly when exposure increase over 85 dB. Continuous exposure to noise is more damaging than short exposure to noise, allowing the ear to rest. The risk of NIHL increases with long-term noise exposure over 80 dB and increases significantly as exposure increase over 85dB.

The most striking feature of NIHL is the degeneration of ciliated cells of the Corti organs. Recently, these lesions and the onset of cellular apoptosis show that they are a result of oxidation caused by presence of free radicals formed by excessive sound stimulation or by exposure to certain chemicals. These findings lead to studies of substances and conditions that can protect cochlear ciliated cells from noise and chemical interference.[7]

The impact of NIHL is a lack of concentration due to an imbalance of the hearing system between the two ears and a difficulty in processing sound sources. The impacts include: fatigue, headaches because the nerves that regulate hearing function are not functioning properly, sleep disturbances because the memory system tries to understand the source of sound which ultimately results in loss of work productivity due to the inability to adapt to work standards.[1]

DISCUSSION

Noisy exposure can produces changes to the cilia hair cells of the corti organs. Stimulation with moderate sound intensity can contribute for mild changes in the sillia and Hensen's body, whereas high-intensity stimulation during long exposure times would make damage to other hair cell structures such as mitochondria, lysosome granules, cell lysis and tearing of the tymphani membrane. The first affected areas are external hair cells, which show a degeneration increasing with the intensity and duration of exposure. Stereocilia on the outer hair cells becomes less rigid, thereby reducing a response to stimulation.

Risk factors that affect the severity of NIHL are noise intensity, frequency, length of exposure per day, length of service, individual sensitivity, age, and other factors that can cause deafness.[1,9,11] Some of the factors that interact with noise are devided into internal factor and external factors. Age, atherosclerosis, hypertension, middle ear disorders and the aging process are several internal factors, while the external factors are abnormal temperature, vibration, drugs or ototoxic substances, and work related to noise [such as construction (construction workers), mining (oil drilling workers, mining workers), transportation (public transport drivers, flying field officers), manufacturing industry (garment, textile, shoe, electronics, automotive, etc), laundry, and catering]. Internal factors lead to mechanical disturbances, metabolic disorders (oxidative stress, excess Ca2), immune disorders and inflammation. Genetic factors include genes associated with oxidative stress, genes associated with K+ metabolism, heat shock protein genes (genes encoding specific proteins). Noise can activate the hypothalamic-pituitary-adrenal axis which regulates the sensitivity of the hearing system plays a role in the cellular mechanisms underlying hair cell death after noise exposure and this causes sensorineural hearing loss.[1,3,5,14] Humans getting older will experience pathological changes in the auditory organs. People who are over 40 years of age will

experience a significant reduction in hearing, so they are more prone to hearing loss due to noise.[9] In external factor, the presence of a transient threshold shift (i.e., temporary hearing loss which mostly disappears 16 to 48 hours after exposure to loud noise) with or without tinnitus is an indicator of a risk that permanent NIHL is likely to occur if noise exposure above threshold continues.[13]

In addition, there are many modifiable and non-modifiable risk factors that can lead to the development of NIHL disorders. The modifiable factors include smoking, diabetes, and lack of exercise. Meanwhile, factors that cannot be modified include aging, race and genetics.[14]

Clinically exposure to noise in the hearing organs can cause an adaptation reaction, an increase in a temporary threshold shift, and an increase in a permanent threshold shift. This is because after exposure to noise, the cochlea which is an immune and an inflammatory reaction occurs within 1-2 days, peaks within 3-7 days, and disappears slowly.[14]

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Symptoms related to hearing loss, such as interference with normal telephone and NIHL.[8] There are various tests to diagnose types and severity of hearing loss, including conventional examinations, such as by recognizing the symptoms and risk factors of NIHL, bone conduction, word recognition, immittance acoustic, autoacoustic emissions, auditory brainstem response and audiometry. However, the most frequently used examination are bone conduction and audiometry.[1] Management of NIHL is permanent/irreversible and cannot be cured, so it does not require medical therapy. Actions that can be applied are to prevent worsening of hearing loss and perform rehabilitation in people who have been exposed to NIHL.[1] Hearing loss treatment must conducted comprehensively starting from prevention to rehabilitation stage.

In general, NIHL cannot be cured, but prevention and rehabilitation can performed. Prevention of hearing loss is an activity or a process to prevent hearing loss. A study in America found that there was a change in behaviour and a number of hearing loss incidents decreased significantly after prevention was applied to employees of an iron company. From the results of this study, it stated that roles of prevention is very important in the incidence of hearing loss. Therefore, it is very important for industries and workers to understand about NIHL so that they can take precautions to overcome this problem.[1] Prevention of NIHL with hearing conservation program (HCP) aims to reduce the risks of NIHL. HCP procedures are noise measurement (monitoring), control of noise, periodic audiometric measurements, hearing protection, worker education, recording and evaluation.[1,2]

A basis for measuring noise is to identify sources of noise such as assessing noise intensity and frequency. Its goal is to assess the maximum, average, minimum, intermittent fluctuation, steadiness of noise.[1] Sound Level Meter and Octave Band Analyzer are used for noise measurement. Outer and changes in the stria vascularis and spiral ganglion neurons are sounds with a frequency of 3000Hz to

8000Hz. A mechanism for NIHL begins with loss of the outer hair cells and, to a lesser extent, of the inner hair of the high-frequency base of the cochlea, followed by a progression of hair cell loss towards low-frequency peaks of the cochlea, symptoms first appearing in the cochlea at frequency 4000 Hz. Hearing loss is usually not noticed in conversations with frequencies of 500 Hz, 1000 Hz, 2000 Hz and 3000 Hz.[1] If high-intensity noise continues for a long time, it can cause deafness. After searching for a noise source, After finding the source of the noise, we then recorded the length of time of exposure The higher the noise intensity, the shorter the allowable exposure period. This has been stipulated in the Indonesian Minister of Manpower Decree no. KEP/51/MEN/1999 regarding the threshold value of physical factors in a workplace (Table 1).[1]

Table 1. Noise Threshold Values[1]

Exposure time (everyday)		Intensity (dB)
8	Hour	85
4		88
2		91
1		94
30	Minute	97
15		100
7.5		103
3.75		106
1.88		109
0.94		112
28.12	Second	115
14.06		118
7.03		121
3.52		124
1.75		127
0.88		130
0.44		133
0.22		136
0.11		139

Noise control can conducted by reducing the amount of noise at noise sources such as noise reduction in an engineering control program, installing silencers, engine insulation, and sound absorbing materials. In accordance with the cause of deafness, sufferers should be moved from a noisy environment, or they use ear protectors such as using an ear plug/mold, a device that is inserted into the ear; this tool can reduce noise by 30-40 dB. Ear muffs/valves can close by themselves when there is a loud sound and open by themselves when the sound is not loud enough.[1,6] Another tool that can be used is a helmet, a head cover that protects the head as well as ear protection. Control noise by performing a machine maintenance that creates noise and creates a sound absorbers or a bulkheads to reduce noise outside an engine

room. The absorbent coating on the inner surface of the machine reduces the build-up of sound echoing inside the machine. The controls used in this element are by installing barriers, covers, silencers, vibration dampers, and sound absorbing materials.[6] This is especially helpful for NIHL patients because the noise as a main cause has been suppressed by a damper which is usually made of cloth or rubber fibres as a sound conduit. At 2017, Cochrane's review found that hearing loss prevention programs with stricter legislation can reduce noise levels.[1]

Hearing check of workers before employees perform work in a noisy environment with pure tone audiometry, are accepted to work in a noisy environment (pre-employment hearing test; the examination includes people living in the noisy environment). The hearing measurement process is conducted regularly, every time or once every six months. This examination is to obtain a basic picture of the hearing ability of workers and the communities in the noisy environment. To find out whether the patient has worsening hearing due to noise or to indicate whether air conduction and bone conduction have occurred so that further evaluation can be done.[1]

NIHL can be prevented by using simple, widely available, and economical tools.[15] Personal ear protection devices can also be used, namely ear plugs and saddles, and personal protective equipment (PPE).[1] Personal noise reduction devices can be passive, active or combine. Passive ear protection includes earplugs or earmuffs that can block sound in a certain frequency. Earplugs and earmuffs can provide its user with an intensity of 10 dB to 40 dB. However, the use of earplugs is only effective if the user understands and uses them correctly. Without proper use, ear protection will not function optimally. Active ear protection, namely electronic hearing aids, pass through hearing protection devices (EPHP) electronically filtering sound with a certain frequency.[1,12]

Education is a key to prevention. Before protective action, they must understand that they are at risks to NIHL and must make choices to take precautions. Hearing protection programs have been hampered by due to a lack of education, a lack of concern about the need for protection, and social pressure on protection.[1,12] A study conducted in Canada stated that there were 250 workers who had adequate education and 250 workers who did not have adequate education of the 500 workers randomly examined in a company. This study found a significant difference in adherence to the use of personal protective equipment indicating that adequate education is better than inadequate education.[1]

Results of the systematic study on the effectiveness of promotion of hearing protection device interventions such as earplugs and earmuffs among workers showed that the interventions showed improved results.[1] The interventions involved the use of appropriate communication to change worker behaviour. Mixed interventions such as posters, distributions of hearing protection devices, noise assessments, and hearing tests are also more effective in improving worker compliance with hearing protection devices than only hearing tests. Communication, information and education are carried out well and strictly enforce the use of PPE by recording and reporting for employees who do not use PPE. Installing posters and signs in noisy areas is an effort that can be applied.[1]

After all procedures have been applied, the last step is to record all the processes that have been conducted. A purpose of recording is to evaluate the noise factors and to determine the next steps such as determining whether it is an occupational disease or not and as a consideration in to improve existing noise sources.[1,12] The recording starts from a source which is a risk factor for noise, followed by recording the frequencies containing in that source; after that evaluation is conducted periodically. Periodic audiometric examinations must also be recorded in order to see the development of the hearing threshold value of workers exposed to noise.[1,12] If workers

experiencing NIHL are worsened, are taken to control the NIHL in relation to noise control, namely exposure at the source, paths, and individual levels. In addition, company actions, such as reducing working hours, arranging breaks, and rotating shifts through noisy areas, can be effective.[1,7,9]

Hearing conservation programs in some installations such as schools and militaries are significantly better compared to other places because of better compliance to regulations.[1,12] This is very different from installations where workers or people do not obey regulations such as unsafe listening behaviour, listening loud noises for long periods of time without protection. Although workers are aware of the risk factors, but not complying is deviating from the regulations. However, it must be understood that hearing conservation programs (HCP) are designed to change behaviour that requires a more direct approach to workers.(1) Therefore, it is important to monitor workers' hearing, to diagnose and to prevent NIHL early through the HCP.[2,8,15]

CONCLUSION

Hearing loss because of noise (noise induced hearing loss) is a decrease in hearing or deafness caused by noise that exceeds the threshold value in a work environment. Risk factors that affect the severity of deafness are noise intensity, frequency, length of exposure per day, length of service, individual sensitivity, age and other factors that can cause deafness. Based on this, it can be understood that an amount of received exposure of noise energy will be similarly proportional as obtained damage. Clinically exposure to noise in the hearing organs can cause an adaptation reaction, an increase in the temporary threshold shift, and an increase in the permanent threshold shift. Hearing loss because of noise is permanent/irreversible and cannot be cured so that it cannot be treated with medical therapy. Its solution is to prevent the hearing loss by hearing conservation programs, such as measuring noise (monitoring), reducing noise risk factors, periodic audiometric measurements, noise control, worker education, and recording.

CONFLICT OF INTEREST

There is no conflict of interest.

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