Risk Factors for increased hearing threshold in workers exposed to continuous and intermittent noise in the heavy equipment industry in North Jakarta

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Abstract. Noise exposure can cause hearing disorders. Both intensity and type of noise contribute to hearing impairment. Different noise types can have different auditory effects. This study aimed to compare changes in hearing thresholds between workers exposed to continuous and intermittent noise. This study employed heavy equipment industry workers at the fabrication and assembly department. Data collected from questionnaires and medical records included age, marital status, cumulative time worked, blood sugar level, blood pressure, smoking habit, hobbies, and results of an audiometric examination. Of total 167 workers, 15 (9%) showed increase in hearing threshold. Of these 15, 13 (86.7%) and 2 (13.3%) had been exposed to continuous and intermittent noise, respectively. Workers aged over 40 years had more than fourfold risk of having an increased hearing threshold. Those who had worked for more than 3.9 years were at high risk of having an increased hearing threshold. Those who were exposed to continuous noise had nearly fivefold risk of having an increased hearing threshold as compared to those exposed to intermittent noise. Workers who are aged over 40 years, have worked in the industry for numerous years, or have been exposed to continuous noise are at increased risk for hearing loss.

1. Introduction
The increasing number of industries in our country places more workers in the industry sector. While the technology used in industry can improve work effectiveness and efficiency, the use of modern machines has some adverse effects, including noise exposure. Workers exposed to noise may experience decreased comfort and peace of mind, hearing loss, and other disorders such as hypertension and stress. In the United States, it is estimated that more than 30 million people experience noise exposure at the workplace, during recreation, or at home. This raised compensation cost for work-related, noise-induced hearing loss (NIHL) was 300 million dollars paid to 50,000 retirees [1].

According to Indonesia domestic legislation passed in 2011 (Indonesian Minister in Labour and Transmigration’s Regulation no. 13), the safe threshold value for noise is set at 85 dB for 8 hours of work [2]. A study of 20 companies in Jakarta during 1990–1991 found that 17 had workplace noise problems [3]. A study of workers in the Dire-Dawa textile factory in Ethiopia showed that the
prevalence of hearing disorders due to noise at the factory is 34%, with a threshold increase of more than 25 dB at 4000 Hz [4]. Another study of construction workers in Edmonton, Alberta, Canada showed that 12.3% of the workers had an increased hearing threshold [5].

While numerous studies have investigated the effects of workplace noise on hearing, few have compared the effects of continuous and intermittent noise. This study aims to compare the changes in hearing thresholds between workers exposed to continuous and intermittent noise and to investigate potential risk factors for hearing loss.

2. Methods
This cross-sectional, comparative study investigated a cohort of workers in the heavy equipment fabrication and assembly industry. The cohort included 167 workers who met the inclusion criteria. Of these workers, 101 were exposed to continuous noise, whereas 66 were exposed to intermittent noise. Primary and secondary data were used in this study. The primary data came from questionnaires filled out by workers while accompanied by a researcher to answer their questions. Secondary data were obtained from employment records and a medical checkup conducted in February 2014, including age, marital status, number of years at this job, blood sugar level, blood pressure, and audiometry results.

The age at the time of the audiometric examination was recorded. Based on age, subjects were divided into two groups (≤40 years and >40 years) because the age-related decrease in hearing threshold due to degenerative processes (presbycusis) begins at age 40 [6]. The audiogram was the outcome of this study. The average hearing threshold was computed using the Fletcher index with a correction for age >40 years old to eliminate increases in hearing threshold caused by aging [7]. Subjects were divided into two groups based on whether their hearing threshold increased, as follows: change ≤25 dB, no-increase group; change >25 dB, increase group.

Statistical analysis was performed using SPSS 20.0. Several risk factors were analyzed to determine whether they were associated with an increase in the hearing threshold as indicated by the audiogram. Variables with p < 0.25 in bivariate analysis were included in the multivariate analysis to identify the significant risk factors.

3. Results
The characteristics of workers according to the type of noise exposure are shown in Table 1. Workers exposed to either continuous noise or intermittent noise were more likely to be married, have no diabetes mellitus or hypertension, have no hobby associated with noise, and to report that their work environment was noisy. The number of smokers did not differ between workers exposed to continuous noise and those exposed to intermittent noise. The age and number of years worked in both groups had an abnormal data distribution, with a median age of 41 years for those exposed to continuous noise and 33.5 years for those exposed to intermittent noise. The median number of working years was 19.3 for those exposed to continuous noise and 9.3 for those exposed to intermittent noise.

Table 1. Cohort characteristics according to noise exposure

| Noise Exposure | Continuous | Median (range) | Intermittent | Median (range) |
|----------------|------------|----------------|--------------|----------------|
| Age            | 41 (20–49) | 32.5 (20–48)   |
| Marital status |            |                |
| Not married    | 10         | 9.9            | 9            | 13.6           |
| Married        | 91         | 90.1           | 57           | 86.4           |
Table 1. Continue

| Noise Exposure | Continuous | Median (range) | Intermittent | Median (range) |
|----------------|------------|----------------|--------------|----------------|
|                | N | %   | N | %   |                      |                      |
| Years working  | 19.3 (1.6–27.1) | 9.2 (1.6–27.1) |
| Diabetes mellitus |             |                |              |                |
| No             | 86 | 85.1 | 52 | 78.8 |
| Yes            | 15 | 14.9 | 14 | 21.2 |
| Hypertension   |             |                |              |                |
| No             | 94 | 93.1 | 60 | 90.9 |
| Yes            | 7 | 6.9 | 6 | 9.1 |
| Smoker         |             |                |              |                |
| No             | 51 | 50.5 | 33 | 50 |
| Yes            | 50 | 49.5 | 33 | 50 |
| Hobby Involving Noise |             |                |              |                |
| No             | 74 | 73.3 | 46 | 69.7 |
| Yes            | 27 | 26.7 | 20 | 30.3 |
| Subjective impression of noise level at work |       |
| Not noisy      | 4 | 4 | 8 | 12.1 |
| Noisy          | 97 | 96 | 58 | 87.9 |

Table 2 shows that the majority of workers who did not experience an increase in hearing threshold were ≤40 years of age; of those who did experience an increase in hearing threshold, most were >40 years of age. The majority of the cohort had been working at their job for >3.9 years. Of the workers experiencing an increase in hearing threshold, more were exposed to continuous noise (86.7%) than to intermittent noise (13.3%). More smokers were among the workers who experienced an increase in hearing threshold than those who did not.

The characteristics of subjects exposed to continuous vs. intermittent noise are compared in Table 3. The age and number of years worked differed between the workers exposed to continuous and intermittent noise. Of the workers exposed to continuous noise, more were >40 years of age. Of those exposed to intermittent noise, more workers were ≤40 years of age. More workers in both exposure groups had worked for >3.9 years. However, the fraction that had worked for >3.9 years was greater among those exposed to continuous noise.

The correlation between risk factors and increased hearing threshold in workers exposed to continuous and intermittent noise is shown in Table 4. Significantly more workers who experienced an increase in hearing threshold were >40 years age (80%) than ≤40 years old (20%) (p = 0.016). Correlation analysis between these groups revealed an OR = 4.44 (95% CI: 1.21–16.4). Thus, workers >40 years old had a four times greater risk of increased hearing threshold than did those ≤40 years.
Table 2. Subject characteristics according to changes in hearing threshold.

| Hearing Threshold   | No Change (%) | Increase (%) |
|---------------------|---------------|--------------|
| **Age**             |               |              |
| <40 years old       | 80            | 3            |
| >40 years old       | 72            | 12           |
| **Marital status**  |               |              |
| Not married         | 19            | 0            |
| Married             | 133           | 15           |
| **Years working**   |               |              |
| <18.6               | 65            | 2            |
| >18.6               | 87            | 13           |
| **Noise type**      |               |              |
| Intermittent        | 64            | 2            |
| Continuous          | 88            | 13           |
| **Diabetes mellitus** |             |              |
| No                  | 124           | 15           |
| Yes                 | 28            | 0            |
| **Hypertension**    |               |              |
| No                  | 139           | 15           |
| Yes                 | 13            | 0            |
| **Smoker**          |               |              |
| No                  | 78            | 5            |
| Yes                 | 74            | 10           |
| **Hobby Involving Noise** |     |              |
| No                  | 108           | 12           |
| Yes                 | 44            | 3            |
| **Subjective Impression of Noise Level at Work** | | |
| Not noisy           | 11            | 1            |
| Noisy               | 141           | 14           |

A significantly higher number of the workers with an increased hearing threshold had worked >3.9 years than >3.9 years (p = 0.043). More of the workers who experienced an increase in hearing threshold were exposed to continuous rather than intermittent noise (p = 0.030) Workers exposed to continuous noise had a nearly five times greater risk of increased hearing threshold compared with workers exposed to intermittent noise (OR = 4.73; 95% CI: 1.03–21.7).
Table 3. Comparison of characteristics between subjects exposed to continuous vs. intermittent noise

| Noise Exposure | Continuous | N | %  | Intermittent | N | %  | p     |
|----------------|------------|---|----|--------------|---|----|-------|
| Age            |            |   |    |              |   |    |       |
| <40 years old  | 43         | 42.6 | 40 | 60.6 | 0.023* |
| >40 years old  | 58         | 57.4 | 26 | 39.4 |       |
| Marital status|            |   |    |              |   |    |       |
| Not married    | 10         | 9.9 | 9  | 13.6 | 0.457 |
| Married        | 91         | 90.1 | 57 | 86.4 |       |
| Years worked   |            |   |    |              |   |    |       |
| <3.9 year      | 14         | 13.9 | 20 | 30.3 | 0.010* |
| >3.9 year      | 87         | 86.1 | 46 | 69.7 |       |
| Diabetes mellitus|        |   |    |              |   |    |       |
| No             | 86         | 85.1 | 53 | 80.3 | 0.413 |
| Yes            | 15         | 14.9 | 13 | 19.7 |       |
| Hypertension   |            |   |    |              |   |    |       |
| No             | 94         | 93.1 | 60 | 90.9 | 0.610 |
| Yes            | 7          | 6.9 | 6  | 9.1  |       |
| Smoker         |            |   |    |              |   |    |       |
| No             | 51         | 50.5 | 32 | 48.5 | 0.799 |
| Yes            | 50         | 49.5 | 34 | 51.5 |       |
| Hobby Involving Noise |        |   |    |              |   |    |       |
| No             | 74         | 73.3 | 46 | 69.7 | 0.616 |
| Yes            | 27         | 26.7 | 20 | 30.3 |       |
| Subjective Impression of Noise Level at Work | 4 |       |   |       |       |
| Not noisy      | 97         | 4   | 8  | 12.1 | 0.065 |
| Noisy          | 96         | 58  | 58 | 87.9 |       |

*statistically significant (p<0.05)

Table 4. Correlation analysis of patient characteristics associated with increased hearing threshold.

| Hearing Threshold | No Change (%) | Increased (%) | OR | CI 95% (range) | p   |
|-------------------|---------------|---------------|----|----------------|-----|
| Age               |               |               |    |                |     |
| <40 years old     | 80            | 52.6          | 3  | 20             | reference 1.21–16.4 | 0.016* |
| >40 years old     | 72            | 47.4          | 12 | 80             | 4.44 |


Table 4. Continue

| Marital status       | Hearing Threshold | OR       | Cl 95% (range) | p     |
|----------------------|-------------------|----------|----------------|-------|
|                      | No Change (%)     | Increased (%) |              |       |
| Not married          | 19 12.5 0 0       | reference |                | 0.222x|
| Married              | 133 87.5 15 100   | -        | -              |       |
|                      |                   |          |                |       |
| Years Worked         |                   |          |                |       |
| <3.9 year            | 34 42.8 0 0       | reference |                | 0.043XX|
| >3.9 year            | 118 57.2 15 100   | -        | -              |       |
|                      |                   |          |                |       |
| Noise type           |                   |          |                |       |
|                      |                  |          |                |       |
| Intermitent          | 64 42.1 2 13.3   | reference | 1.03–21.7       | 0.030*|
| Continuous           | 88 57.9 13 86.7  | 4.73     |                |       |
|                      |                   |          |                |       |
| Diabetes mellitus    |                   |          |                |       |
|                      |                  |          |                |       |
| No                   | 124 81.6 14 93.3 | reference |                | 0.473x|
| Yes                  | 28 18.4 1 6.7    | 0.32     | 0.04–2.51      |       |
|                      |                   |          |                |       |
| Hypertension         |                   |          |                |       |
|                      |                  |          |                |       |
| No                   | 139 91.4 15 100  | reference |                | 0.610x|
| Yes                  | 13 8.6 0 0       | -        | -              |       |
|                      |                   |          |                |       |
| Smoker               |                   |          |                |       |
|                      |                  |          |                |       |
| No                   | 78 51.3 5 33.3   | reference | 0.69–6.46      | 0.184 |
| Yes                  | 74 48.7 10 66.7  | 2.11     |                |       |
|                      |                   |          |                |       |
| Hobby Involving Noise|                   |          |                |       |
|                      |                  |          |                |       |
| No                   | 108 71.1 12 80   | reference | 0.17–2.29      | 0.561x|
| Yes                  | 44 28.9 3 20     | 0.61     |                |       |
|                      |                   |          |                |       |
| Subjective Impression of Noise Level at Work | | | | |
|                       | No                |          |                |       |
|                      |                   |          |                |       |
| Not noisy            | 11 7.2 1 6.7     | reference | 0.13–9.10      | 1.000X|
| Noisy                | 141 92.8 14 93.3 | 1.10     |                |       |

*statistically significant (p<0.05)

Other risk factors, including marital status, diabetes mellitus, hypertension, smoking habit, noise-related hobby, and subjective impression of the noise level at work, had no statistically significant correlation with an increased hearing threshold (p > 0.05 for all).

Multivariate analysis using logistic regression was conducted to determine the interaction of the variables and to identify the main determinant variable for increased hearing threshold. The method used was backward LR (Logistic regression). The dependent variable in this analysis was the hearing threshold; the independent variable chosen for this analysis had a value of p < 0.25 in bivariate analysis. The selected variables were age, type of noise, and smoking habit.
Table 5. Dominant factors in hearing threshold increase

|                          | Sig | Exp (B) | Min   | Max   |
|--------------------------|-----|---------|-------|-------|
| Age &gt;40 years old     | 0.049 | 3.775 | 1.009 | 14.126 |
| Continuous noise         | 0.083 | 3.916 | 0.839 | 18.280 |

The final results in Table 5 show that the main determinant factor for an increased hearing threshold is age. After adjusting for the type of noise and smoking habit, workers &gt;40 years of age had nearly four times the risk of experiencing increased hearing threshold compared with workers ≤40 years of age.

4. Discussion

Our results show that of the 167 workers studied, 15 (9%) experienced an increase in hearing threshold. Thirteen of these workers (86.7%) were exposed to continuous noise, whereas 2 (13.3%) were exposed to intermittent noise. This result reflects the observation that exposure to continuous noise is more destructive than intermittent noise [8].

The ages of the workers differed between those exposed to continuous and intermittent noise. However, an increased hearing threshold was observed in workers with &gt;40 years of age, regardless of the type of noise exposure. Of the workers experiencing an increased hearing threshold, 12 (80%) were &gt;40 years of age, with p = 0.016 indicating a correlation between age and increased hearing threshold. Workers with &gt;40 years of age had more than four times the risk of an increased hearing threshold compared with those ≤40 years of age (OR = 4.44; 95% CI: 1.2–16.4). This result is consistent with those of Masilamani et al., who found that an increase in hearing threshold due to noise correlates significantly with age &gt;40 years [9]. Miller et al. found that aging mice, with or without presbiacusis, are more sensitive to noise-induced hearing loss [10]. Strauss et al. observed an increase in the hearing threshold of workers at a frequency of 6000 Hz starting at the age of 41 years, regardless of noise exposure. Similar to our observations, another study reported that workers &gt;40 years of age are more likely to experience an increase in hearing threshold [11].

All of the 15 subjects, who experienced an increase in hearing threshold, were married. Statistical analysis (p = 0.222) indicates no correlation between marital status and increased hearing threshold. In 2009, the American Academy of Otolaryngology found that of 5290 subjects, 13% suffered from deafness caused by noise. Noise-related deafness was more frequent in men than women, and in married than unmarried subjects. However, there is no scientific explanation of how marital status could affect hearing loss due to noise. No other studies have investigated this phenomenon [12].

A significant correlation between the number of years worked and an increase in hearing threshold (p = 0.043) was observed and that the minimum number of working years that correlated significantly with an increased hearing threshold was 3.9 years. Taylor et al. found an increase of 10–15 dB in the hearing threshold at frequency of 4000 and 6000 Hz in workers exposed to noise of 87–101 dB during 1–2 years of work [13]. Our finding of 3.9 years was higher because the noise exposure in this study was lower than that of the study by Taylor et al. According to Standard Otolaryngology, early changes in young adults who are exposed to noise for 1–2 years appear at a frequency of 6000 Hz. After working for 2–5 years, there is a permanent increase in the hearing threshold at a frequency of 4000 Hz [14]. Thus, the increase in hearing threshold due to noise begins after working for 1–5 years, which is consistent with our result of 3.9 years. The number of years worked provides an estimate of how long a worker has been exposed to noise in the workplace, even though it cannot provide an exact exposure calculation. The longer the number of years worked, the longer the exposure to noise and the greater the risk of hearing loss.
This study observed that more of the workers who experienced an increased hearing threshold were exposed to continuous noise (86.7%) than intermittent noise (13.3%) (p = 0.030). These results are consistent with those of Chung et al., who observed a correlation between the type of noise exposure and hearing loss in workers (p < 0.0001), with more hearing loss in those exposed to continuous noise [15]. During intermittent noise exposure, the increase in hearing threshold is temporary because the noise eventually stops. During this rest period, the irregular, damaged hair cells and stereocilia cells gradually recover, so that the hearing threshold normalizes. In contrast, continuous noise exposure results in permanent damage to hair cells and stereocilia because there is no recovery time [8]. Thus, an abnormal hearing threshold is observed more in workers exposed to continuous noise than intermittent noise.

Diabetes mellitus can cause chemical changes in the auditory nerve cells so that signal transfer to the brain is disrupted. Horikawa et al. showed that people with diabetes mellitus have double the risk of hearing loss than do those without [16]. Only 16.8% of the workers in our study had diabetes mellitus, and only one of those (6.7%) experienced an increased hearing threshold. With p = 0.473, we observed no correlation between diabetes mellitus and hearing loss.

Cells in the auditory organs require sufficient oxygen intake to function. Hypertension causes circulatory disturbances such that oxygen intake into auditory organs decreases, causing hearing loss. Marchiori et al. found a correlation between hypertension and hearing loss (p = 0.0034) [17]. In our study cohort, the prevalence of hypertension was only 7.8%. None of the workers who experienced an increase in hearing threshold had hypertension. Thus, no correlation was observed between hypertension and hearing loss. These results may differ from those of previous studies because of differences in the study design.

Nicotine and carbon monoxide contained in cigarettes may reduce the oxygen flow to the cochlea, resulting in hypoxia in hair cells that eventually causes hearing loss. Sung et al. found that smoking significantly affects hearing loss at all frequencies in workers exposed to noise [18]. Mizoue et al. concluded that smoking is a risk factor for hearing loss at high frequencies and has additive effects with noise exposure [19]. However, Syafei found no correlation between smoking and hearing loss, as determined by both DPOAE and audiometry [20]. In our study, 66.7% of the workers who experienced an increase in hearing threshold were smokers. With p = 0.18, no correlation was observed between smoking and hearing loss. This result is consistent with that of Syafei D, likely because the criteria were similar to those used in our study (smoker vs. non-smokers). In contrast, Sung et al. divided the cohort into three groups: non-smokers, former smokers, and smokers. Mizoue et al. divided their cohort into non-smokers, smokers of 1–14 cigarettes/day, smokers of 15–24 cigarettes/day, and smokers of ≥25 cigarettes/day.

The perception of noise can be subjective. People exposed to noise in the same place may have different opinions about whether or not the place is noisy. Few studies address the relationship between the subjective perception of noise and hearing loss. Beach et al. found a correlation between subjective noise estimates and the objective measurement of L\text{eq} [21]. In our study cohort, more workers said that their working environment was noisy, whether or not they experienced hearing loss. However, of the workers who experienced an increased hearing threshold, 93.3% said their working environment was noisy. The average L\text{eq} measurement was over 85 dB, indicating objectively that their workplace was noisy. Thus, a good subjective noise impression should be able to play a role in the effort to prevent hearing loss due to noise. If a worker feels that their working environment is noisy, they can take action to minimize the effect of noise exposure, for example, by avoiding noisy areas or using ear protection. Of the 155 people who said that their workplace was noisy, only 14 experienced an increased hearing threshold. Perhaps the other 114 people made an effort to prevent hearing loss by using ear protection. This possibility can be addressed by looking at the surveillance reports on the use of ear protection at the workplace.

Multivariate analysis of age, type of noise, and smoking showed that age was the main determinant factor in the incidence of increased hearing threshold. After controlling for type of noise
and smoking habit, workers >40 years of age had a risk of increased hearing threshold nearly four times that of workers ≤40.

The limitation of this study is that noise was measured in the work environment using the “grab method,” in which the instantaneous noise is measured at each chosen point. Individual noise measurements could not be performed using noise dosimeters, which provide accurate data on exposure doses received by workers in noisy areas. Additionally, the results of the audiometric examination obtained could not be compared with previous audiometric examination results because different audiometers were used in the previous examinations. Additional data were obtained from the questionnaire; some or the questions relied on memory, so the subjectivity of the answers was high.

5. Conclusion
In our study cohort, 60.5% of the workers were exposed to continuous noise, and 39.5% of the workers were exposed to intermittent noise. Most workers were >40 years of age and had been working for >3.9 years. An increase in hearing threshold was experienced by 15 subjects (9%). Workers exposed to continuous noise experienced an increase in hearing threshold of as much as 86.7%; workers exposed to intermittent noise experienced an increase in hearing threshold of as much as 13.3%. Continuous noise was more risky, causing five times the increase in hearing threshold as intermittent noise. No statistically significant correlation was observed between increased hearing threshold and marital status, hypertension, diabetes mellitus, smoking, noise-related hobbies, or the subjective perception of noise. A positive correlation was observed between increased hearing threshold and the age and years worked.

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