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Review Article

Effects of Noise Hazards towards Physiology Especially Heart Rate Performance among Worker in Manufacturing Industry and Their Prevention Strategies: A Systematic Review

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Abstract

Background: Occupational noise exposure is one of the environmental factors that pose safety and health risks among workers in factories. This systematic review focuses on the activities that cause noise hazards toward workers' heart rate, other physiological conditions, and strategies to prevent noise exposure in the manufacturing industry.

Methods: Through a comprehensive literature review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and the Cochrane method were used. The appraisal of quality was conducted by using the Critical Appraisal Skills Programme (CASP) to fulfil the selected keywords.

Results: Occupational noise exposure not only affects the workers' most common issues, such as heart rate, but also other physiological factors, such as blood pressure. The outcome showed that different level of continuous noise exposure with high intensity decibels affects the heart rate of the workers. Source, path, receiver was recommended strategies for basic noise prevention in engineering control.

Conclusion: Therefore, noise give significant effects towards human workers in related industry. Study related to noise effects towards heart rate performance led to future prevention and innovation.

Keywords: Sound; Heart rate; Factory; Safety; Environment

Introduction

Noise can be defined as any unwanted sound that irritates or distracts people, which can cause an adverse psychological or physiological effect on humans (1). Noise implies harmful effects toward people and the environment if left uncontrolled (1). Moreover, it is one of the environmental problems related to human factors in daily life. High noise level or noise pollution can lead to safety and health problems. It can also cause hearing loss and increase heart rates. Noise pollution has been recognized as a crucial worldwide challenge that impacts the quality of life in urban areas (2). Continuous noise of approximately 85–90 dBA leads to loss of hearing in industrial environments (3).

WHO estimates that this auditory effect has potentially caused approximately 10% of noise-induced hearing loss, where almost half of the sufferers have been exposed to intense noise that led to auditory damage (4). Noise exposure nowadays has been associated with a range of non-auditory health effects, such as annoyance (5,6). A substantial amount of research on the effect of noise related to hearing loss and communication interference has been conducted. To fill the gaps of the existing studies and cover a holistic scope about the effect of noise, non-auditory effects must be determined to validate whether they contribute to the effects of noise on safety and performance.

The non-auditory effects of noise are also a major concern in terms of safety and health. Several studies have identified a number of these effects, including annoyance (5,6) cardiovascular disease such as increased heart rate (7,8) sleep disturbance (9), mental disorders, and undesirable physiological and psychological impacts (10). The most major concern has been the impairment of cognitive faculties among children (11). Noise can affect a person's heart rate and change the blood composition (12). Therefore, the National Institute of Occupational Safety and Health (NIOSH) has set the recommended exposure limit of 85 dBA as the average sound pressure level for occupational noise exposure for individuals working for eight hours (13).

Therefore, several methods or assessment for noise pollution has been studied. Reducing noise localized in certain parts of the voice spectrum has been introduced by researchers (14). The adaptive cancellation of localized environmental noise shows that a filter is suitable for reducing environmental noise in speech applications (14). One study examined the indoor environment of a mosque to ensure the comfort of the users (15). Knowledge about occupational stress helps the manager or an organization created opportunities for intervention (16). In alleviating occupational stress, workers need both organization and individual cooperation in reducing each stressor (16). One study proposed a novel method to prevent hearing loss due to occupational noise-induced hearing loss among students in Malaysia undergoing furniture industry skills training (17). They used the Octa hearing conservation index (OHCI) system in the institutions to monitor and manage the hearing conservation program (17). This method showed that the participants exhibited improved alertness on the hazards mostly on loud noise exposure, and the method educated them to wear hearing protection devices actively (17).

A study on the measurements of noise level and its analysis for industrial projects in Malaysia was done with three different phases, namely, existing environmental noise level, noise scenario during the construction stage, and noise contours predicted during the operation stage (18). Researchers in Ontario, Canada investigated noise in working environments. They used the data convergence of the noise measurements (quantitative data) with the survey responses (qualitative data) (19). The results from their study showed that the workers examined did not perceive the noise as annoying even though the noise measurement exceeded 85 dBA (19). Meanwhile, a study on rubber manufacturing showed that noise exposure had an additive effect on the occurrence of hypertension (20). An increase in the prevalence hypertension was associated to noise exposure higher than the permissible limit (20). In the forging industry in India, the established workforce of forging units was at high risk of the chronic effects of occupational noise (21). These experimental and industrial findings have significant results that indicate that heart rate can be affected with increasing noise exposure.

Therefore, the objective and aim of this systematic review were to study the occupational noise level and its impact on workers' safety and health especially in terms of heart rate problems in the manufacturing industry and related workplaces. The effect of noise exposure can have physical and psychological impacts on a worker's life. By applying formal standard systematic approach and investigation, this review paper plays a major role in explaining the effects of noise exposure on the heart rate among workers in the manufacturing industry and forecast future deep research on these issues.

Methods

This work focused on the connection between occupational noise exposure and the physiology parameters among workers. In this systematic review, the authors aimed to highlight the effect of workers' physiology measures in the form of heart rate caused by noise hazard in the workplace particularly in the manufacturing industry. The studies for this review were retrieved by searching specific and reliable databases from Scopus, Web of Science, PubMed and Science Direct. The organized selection process was performed using guidelines retrieved from the Cochrane method and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (22,23).
Furthermore, methodological elements considered in this study, including research questions and inclusion and exclusion criteria quality appraisal, were established. To fulfil selected criteria articles that would comprise the keywords selected, the appraisal of quality was conducted by using the Critical Appraisal Skills Programme (CASP) 2019 (24). The CASP tool is a frequently used grading method for quality assessment in qualitative evidence synthesis. This tool is often used in the analysis of health-related studies with support from the Cochrane Qualitative and Implementation Methods Group (25).

Research Questions

This systematic review aimed to provide a compilation of research related to the effects of occupational noise on heart rate parameters among workers in the manufacturing industry. Hence, three main research questions (RQ) have been formulated in more detail. The following relationships will be investigated.
RQ1: Type of activities and work environments in the manufacturing sector(s) that cause noise hazard. RQ2: Effects of noise hazard toward workers' heart rate and other physiological measures.
RQ3: Strategies to prevent noise effects.

Keywords Identification

Keyword identification were determined based on RQs listed in research questions and research scope. Related keywords listed and used were as follows; (i) noise hazard, (ii) manufacturing industry, and (iii) heart rate. Table 1 shows the list of key terms used to identify and select related articles with the main keywords. The database of SCOPUS, Web of Science (WoS), PubMed and Science Direct were used to search related keywords and their synonym.

Table 1: Keywords and Synonyms

Keywords	*Synonyms*
Noise hazard	Industrial noise, machinery noise, factory noise, occupational noise, occupational noise hazard, industrial noise hazard, machinery noise hazard, factory noise hazard
Manufacturing industry	Manufacturing industry
Heart rate	Heart rate

Article Searching, Screening and Selection

The screening method used for inclusion and exclusion criteria. The selections were based on the most significant terms and then were refined in the title, abstract and keywords from the original research papers. There were three different types of keywords and the synonyms applied into databases. The difference between these three types of keywords presented is by the placement of double quotation mark. For informational purpose, the replacement of the double quotes chosen by the researcher is to get an accurate search through in an extensive database.
Based on this search method, keywords for noise hazard were decided to imply by adding synonyms listed so that further procedure search steps can be performed as shown in Table 1. In addition, the keywords for the manufacturing industry and heart rate were used as stated in Table 1. Screening and selection strategy were discussed as follows:
Type 1 (n); "double quotation mark on all the keywords":

Type 2 (n); "double quotation on noise hazard keyword only":
Type 3 (n); "double quotation on both manufacturing industry and heart rate":
By listing all three types of keywords searching strategy, authors decided to choose Type 3 whilst Type 1 and Type 2 excluded. The reason behind the decision is both Type 1 and Type 2 resulted 46 and 213 articles in total while Type 3 resulted 401 articles. There is one thing to be address that Type 3 (ii) excluded from the keyword searching strategy because resulted way too many articles even with refining the filter of year and document type with total of 200,000 plus articles. Searching procedure was refined by selecting filters such as years range (from 2000 until 2020) as inclusion criteria and document type (research articles and review paper). The articles in initial search were identified and ensured the selection criteria have been met. All studies involving worker-related information in manufacturing industry and noise hazard affecting worker were included in this review. Any article without mentioning heart rate and all inclusion criteria were excluded are classified as exclusion criteria.

Article Analysis

All articles were analysed of the relevant evidence sources after the evaluation process. The results and details from the selected articles have then been investigated based on the corresponding aspects prior to drawing a conclusion. Based on the analyses, the relation between noise hazard and heart rate was identified. Fig. 1 explains the methodological used in the systematic review process by using PRISMA guideline (26). The quality assessments of the 10 articles were represented by strong relevance for the comprehensive overview of the study. The CASP tool assisted to summarise the criteria of each element according to its strengths and potential flaws. Figure 1 presents the quality assessment of each article selected and analysed.

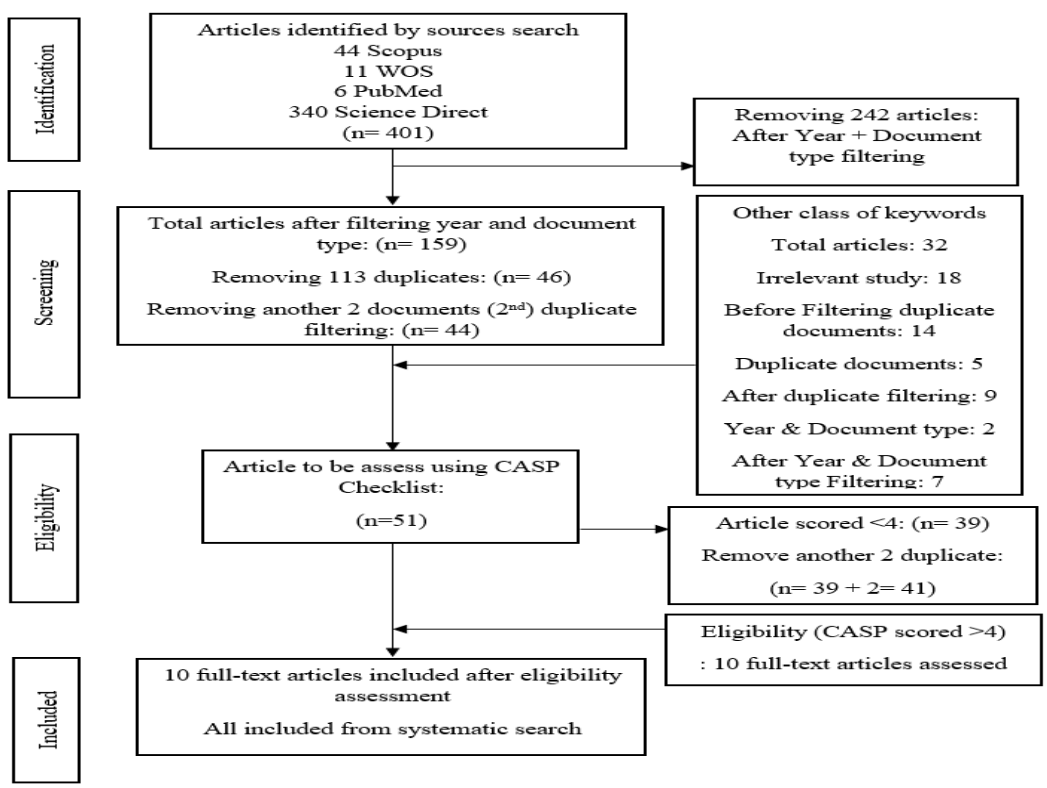

Fig. 1: PRISMA Guideline

Appraisal and Eligibility

The selection of each article was based on the following factors: precise and clear objective or hypothesis of studies, sample size, sectors, methods, and comprehensive statistical analysis. Review papers or systematic review papers were excluded. The appraisal of quality was conducted by applying the CASP Checklist (24). The list consisted of ten questions, which focused on study validity, results of the study, and the question on whether the selected articles would be helpful locally or not. Table 2 shows the score of each article based on CASP Checklist after the entire article has been appraised.

Table 2: CASP Checklist Score for Qualitative Research

CASP Checklist		***t***
No.	First Author	
1	Mo et al. 2011	6
2	Lusk et al. 2015	7
3	Björ et al. 2007	7
4	Gupta et al. 2017	6
5	Lai et al. 2019	5
6	Chang et al. 2015	6
7	Zamanian et al. 2013	5
8	Ismaila et al. 2014	6
9	Chen et al. 2015	6
10	Kalantary et al. 2015	7

Results

This study identified (n=401) articles that used the selected keywords search strategy from four search established databases. At the primary assessment level, this study excluded (n=242) articles as they were irrelevant and duplicated articles. Overall, 41 articles related to occupational noise were unrelated to heart rate performance and vice versa according to their abstracts. Conclusively, this study included (n=10) articles in the meta-analysis because of their relation to the objective of the current study. In this review, past study related have two types. There were three laboratory setups, and seven experiment of industrial setups were involved in the collection of the studies. Table 3 shows the summary of the related results needed in this study that was adapted from Myzabella et al. with a few changes to suits this study better (37).

Discussion

Conclusively, this section describes 10 articles based on Table 3, which reinforces the eligibility of the detailed analysis in responding to the RQ of the current study. Overall, noise hazards can affect an employee's heart rate. Several previous studies (27-29) do not directly mention the harmful effects of noise hazards toward heart rate. However, these hazards also affect workers physiologically and contribute to cardiovascular problems. Therefore, for previous studies that did not describe these direct effects, the authors have researched in detail the important factors related to the effects of noise on heart rate in qualitative and quantitative aspects.

Type of Activities and Work Environments that Cause Noise Hazard

According to the findings, noise is initiated from the surroundings of the working condition. Noise is initiated by either the industrial surrounding or noise adaptation from laboratory setups.

Three of the past studies were carried out in a laboratory setup (29, 35, 36). However, the noise recordings were recorded from actual work environments. Björ et al. used a laboratory setup by applying the vibration exposure obtained from two handles mounted on an electrodynamic shaker and driven by a power amplifier (35). They set up the vibration on the x-direction (10 Hz) and chose to resemble the vibration content of a rock drill used in the mining industry.

Table 3: The summary of the related results

Reference	*Sector*	*Participants*	*Methods*	*Recorded results*	*CASP Score*
Mo et al. 2011, (36)	Laboratory	20 women and 20 men	Standard man-machine experiment	Heart rate variability (HRV) has significantly influenced by the factors of experimental phase.	6
Lusk et al. 2015, (34)	Auto Assembly Plant	46 workers	Workers wore blood pressure monitor and noise dosimeters	Physiological effect of noise to be concluded that it is appeared acute and chronic. Heart rate being affected by instantaneous peak noise.	7
Björ et al. 2007, (35)	Experiment	10 male and 10 females	Questionnaire and test	Heart rate increased over time of exposure.	7
Gupta et al. 2017, (32)	Textile Mill	120 male workers	High/Low noise exposure	Heart rate significantly increased in high noise group.	6
Lai et al. 2019, (30)	Experiment (variety of workplace)	Groups of participants working on environment with noise	5-year health examination	Indicative difference in Body Weight, Waist, Heart rate, BUN, Uric acid and total cholesterol.	5
Chang et al. 2015, (27)	Experiment	20 volunteers	Experimental setup	Exposure of occupational noise can sustain effects on vascular properties not transient them plus it also enhancing hypertension development within two environments of low and high intensity noise.	6
Zamanian et al. 2013, (31)	Steel Industry	50 workers	Cross-sectional study	Before and after acute exposure of 85-, 95-, and 105-dB noise levels, no significant difference of blood pressure and heart rate was observed.	5
Ismaila et al. 2014, (28)	Sack Manufacturing	62 random male workers (from 6 sections)	Assessed noise exposure	Recorded systolic blood pressure increased. In addition, no indicative increase in workers' diastolic pressure.	6
Chen et al. 2015, (29)	Cleanroom	10 male and 10 females	Treatment combinations	Discomfort feeling and physiological cost is increased when exposed to prolonged noise intensity.	6
Kalantary et al. 2015, (33)	Automotive	26 workers	Sound pressure (Calibrated instrument)	Industrial noise exposure may increase workers' heart rate, systolic and diastolic blood pressure.	7

The Heart Rate Variability (HRV) had significant effects towards four exposure condition and found that no difference between males and females volunteers. The noise level range and frequency were selected based on the industrial noise status to be performed in their experimental work (36). For the experimental noise with respect to the available domestic and international standards, the center frequencies of octave were used as the frequencies. The limit value of 65 dBA was specified as the minimum value; the highest value was 90 dBA. The changes were made only on different environments based on the industry noise adaptation.

The semiconductor industry, known to use cleanrooms, is also vulnerable to noise hazards. Field investigation was conducted by recording the noise frequency and noise intensity at two levels (high and low) at the wafer manufacturing section (29). A simulated experiment was then performed by using a low value (65 dBA) and a high value (80 dBA) of noise level intensity and adapted both values in the laboratory. Subjective fatigue feelings and annoyance were the effect that occur from the noise exposure at 65 dBA for 50 min and noise exposure at 80 dBA for 10 min (29).

In this review, there were seven other studies conducted industrial setup experiments. Three studies reviewed were conducted noise assessment in the automotive industry. Multiple methods were conducted to investigate the relationship between heart rate and blood pressure with few variables in an automotive engine assembly plant (34). A personal dosimeter was used to measure the noise exposure throughout working hours. The workers' noise exposure levels in this automotive plant ranged from 40.7 to 145.2 dBA. Study shows significant increases in systolic blood pressure (SBP) and diastolic blood pressure (DBP), heart rate also affected by instantaneous peak noise (34).

Chang et al. selected twenty workers with two categories of noise exposure in an automotive company (27). Fifteen workers were chosen. These participants were exposed to high levels of noise from operational units that performed press forging, engine manufacturing, body assembly, and roller and track trial testing. Another five workers were chosen, as they worked within an environment with low-noise exposure. Kalantary et al. demonstrated other work sections in the automotive industry that were exposed to noise hazards (33). These sections had heavy pressing, manual pressing, cutting, and metalworking lathes.

Textile milling was also another industry that contributed to noise hazards (32). Different noise levels were found in the following work sections inside the textile milling: weaving (95-100 dB), spinning (90-95 dB), and packaging (70-80 dB). Ismaila et al. investigated the impact of noise hazards in the sack manufacturing industry in six different work sections as mentioned earlier (28). The highest noise values were obtained in the PG (approximately 104 dB), followed by TF (approximately 95 dB), FPS (approximately 92 dB), GT (approximately 90dB), SL (approximately 85 dB), and CPL (nearly 80dB). Zamanian et al. conducted a different style of experiment by recording the noise exposure in the steel industry before playing it back to the workers inside the industry (31). All workers were exposed at three levels (85, 95, and 105 dB).

Effects of Noise Hazard toward Workers' Heart Rate and/or Other Physiology Measures

Six studies clearly reported a significant rise in heart rate and blood pressure in response to noise exposure (30, 32-36). All frequency noise would clearly accelerate the heart rate (36). These conditions still occurred after noise exposure was withdrawn or terminated. Noise exposure had a sustaining effect not only when noise existed but also after noise withdrawals.

Other studies conducted the in-depth relationship between heart rate and blood pressure with noise. Weaving activities in textile mills contributed to the highest level of HR and BP values with noise levels between 95 to 100 dB (32). Furthermore, the HR was significantly affected with an average increase of 3 bpm for each 10% increase in minutes of exposure by the percentage of non-missing peak noise levels (34). In addition, a 2-mmHg increase in systolic BP was associated with each 10-dBA increase in the average noise.

However, a contrasting finding was observed by Zamanian et al. on the impact of noise exposure toward heart rate (31). The results showed no significant difference in blood pulse and heart rate before and after the exposure with different noise levels. This finding was also similar to Chen et al., which indicated no significant exposure time differences between heart rate and noise sensitivity (29). However, an investigation on the semiconductor industry showed an increment of blood pressure when individuals were exposed to high frequency and high intensity at 80 dBA.

The other two articles indirectly mentioned the effect of noise hazard toward workers' heart rate by demonstrating its relationship with other single physiology measures, such as hypertension, blood pressure, and cardiovascular parameters (27, 28). Human emotional stress was also reflected by heart rate (36). Thus, the condition of human emotional stress could be seen by observing human heart rate. Increases in heart rate, blood pressure, and stress hormones were associated with emotional or physical stress (36).

Ismaila et al. investigated the impact of noise hazard in the sack manufacturing industry by taking blood pressure data from three periods: morning, night, and off day (28). The systolic blood pressure exhibited different patterns of increment based on the noise level category. The systolic blood pressure for all types declined steadily from noise levels at 86 dB to 89 dB. However, an increment pattern was indicated from 89 dB to 91 dB. Then, the decrement pattern from the range of 91 dB moved to approximately 95 dB before it increased again until the maximum noise level in the factory was reached.

Regarding the relationship between noise exposure and cardiovascular parameters, Chang et al. found a significant association between both variables in terms of brachial artery compliance (BAC; %mL/mmHg), brachial artery distensibility (BAD; %/mmHg), brachial artery resistance (BAR; mmHg/L/min), systemic vascular compliance (SVC; mL/L/mmHg), and systemic vascular resistance (SVR; mL/L/min). Workers with a noise dose of 85 ± 8 dBA had lower means of 1.00 to 2.00 %mL/mmHg of cardiovascular parameters (27). In addition, significantly lower levels of BAG, BAD, and SVC were recorded among workers with a family history of hypertension. The SVC was also higher among workers with longer employment duration. Overall, heart rate showed significant increments with stress response, exercise, and type of activity (34).

Relationship of Noise Exposure toward Heart Rate

From this review studies, noise gave significance relationship towards physiology of worker especially heart rate. The worker experience heart rate changing over the noise variation level. This can be found in papers than has been reviewed. Most of the workers having physiological effects due to variability of noise in difference situation that has been setting in previous researchers. Table 4 showed the relationship various level of noise exposure toward heart rate in reviewed paper.

Table 4: Relationship of noise exposure toward heart rate

Variable	*Level of Noise (dB)*		
	<70 dB	85 dB	>95 dB
Noise Exposure	4	7	6
Heart Rate Effects	3	5	5
% of studies depth different noise level			
Noise Exposure	40%	70%	60%
Heart Rate Effects	30%	50%	50%

From this study, previous researcher is more focus on studying the effect of noise from 85 dB until more than 95 dB. Where all these studies show the significant findings that show the higher level of noise exposure can affect the heart rate. While the percentage of depth of studies that focus on level of noise from 85 dB (27-28, 31-35) and more than 95 dB (28, 31-34, 36) is about 70% and 60% respectively with heart rate effects shows same percentage of 50%. Figure 2 shows the positive linear trends of studies and focus of research on comparing the level of noise with the heart rate effects. Researcher focus on finding the significant effect of exceeding the OSHA permissible level of noise (13, 20).

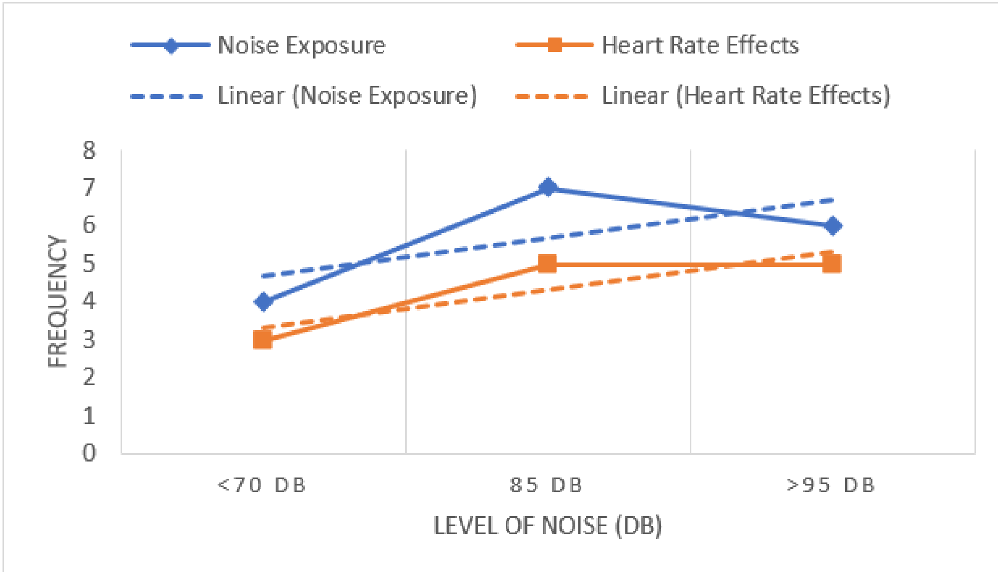

Fig. 2: Focus of studies on noise level

Practical Implications and Strategies to Prevent Noise Effects

The manufacturing industry is the biggest contributor of incidents that cause permanent disability and death, as reported by the Department of Safety and Health (DOSH) (38). However, such incidents can be reduced or prevented if the related authorities of companies, such as designers, took more opportunities to address these issues (39). Such initiatives are favorable in reducing incidents in the industry. They can allow employers to understand employees by conducting experimental or industrial procedures and designing proper and safe workplace measures. In addition, DOSH Malaysia has stated their guidelines on noise control basic strategy. This strategy has three types, namely, control at the source, reduction in the path, and reduction in the receiver (38). As for basic treatment strategies that have been used in engineering controls, the reduction of noise is associated with each strategy. Noise reduction for the control at the source is 6 to 8 dB, that for the reduction in the direct path is 10 to 25 dB and up, that for the reduction in the indirect path is 4 to 6 dB, and that for the reduction at the receiver is 10 to 25 dB and up. Figure 3 shows the possible noise control related to the source, path, and receiver.

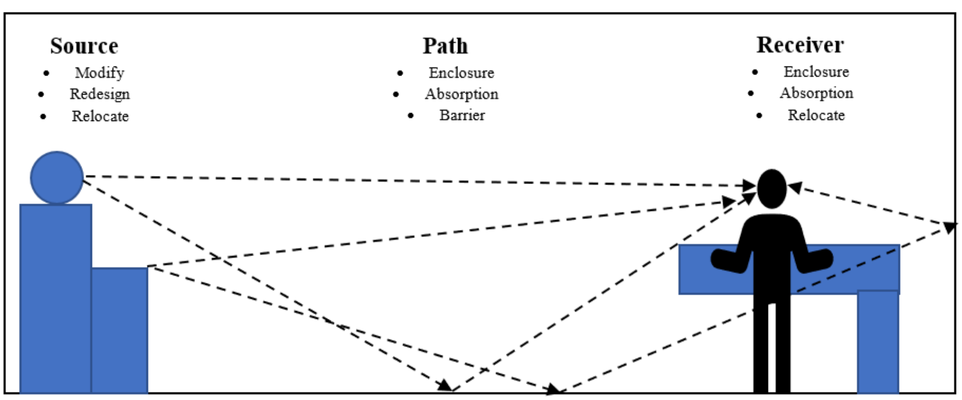

Fig. 3: Possible noise control (Source: DOSH)

Figure 3 demonstrated that noise exposure could be prevented and reduced with three types of strategies. In the hierarchy of control, the most effective is noise reduction at the source through elimination and substitution. Then, the next effective method is engineering control at the path to reduce the noise. Meanwhile, the least effective is exposure reduction at the receiver with administrative control and hearing protective device (HPD).

Hearing aids are highly recommended when faced with varying levels of noise. The use of HPD not only helps reduce noise exposure, but it is also associated with a decrease in physiological parameters particularly systolic blood pressure and HR value. It is in line with Lusk et al. that validated hearing protection devices can help to reduce the systolic BP by 5.5 mm Hg (34).

In Malaysia, ischemic heart disease caused the most deaths recorded in 2019 (40). One study resulted in a worrying outcome. The outcome particularly for the sudden cardiac death of middle-aged men with increased heart rate is a risk factor for fatal ischemic heart disease events (41). Even so, we did not find any reliable sources on the Internet on the percentage of the manufacturing industry employment to be studied. We also could not correlate the staggering data of the causes of death by heart disease among Malaysians. Thus, further study is needed to search for mass and relevant sources.

Conclusion

Various work sections in the manufacturing sectors are exposed to noise hazard. Prolonged exposure to occupational noise may result to poor physiological measures, particularly not only heart rate but also blood pressure. Increased heart rate can escalate the cardiac blood supply. Heart rate can be influenced by environmental noise exposure, thus reflecting emotional stress. Furthermore, the human working state and labor safety also can be affected by the uncontrolled noise exposure. Therefore, the heart rate is chosen as an assessment index to study noise exposure at the workplace in relation to human heart load. Continuous uncontrolled exposure to occupational noise may lead to adverse changes in blood pressure, that is, mild risk to moderate risk, depending on the intensity of noise. It may also trigger cardiovascular abnormalities, such as stroke and myocardial infarction. Occupational noise exposure with higher intensity (more than 90 dB) may be associated with hypertension problems. Thus, strategies must be implemented to prevent and reduce noise exposure for high and low intensities. Such solutions include enhancing machine tool maintenance; improving engineering control; implementing job rotation with competent administrative control; providing personal protective equipment, such as HPDs; and ensuring adequate supervision to facilitate the quality of working life and job satisfaction.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interest.

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