UNIVERSITI PUTRA MALAYSIA

CO-EXPOSURE OF PM2.5 AND NOISE AMONG AUTOMOTIVE WORKERS AND THEIR CARDIOVASCULAR HEALTH STATUS AT A SELECTED AUTOMOTIVE MANUFACTURING INDUSTRY IN SELANGOR, MALAYSIA

ANEESAH AMANI BINTI SUFFIAN

lp
FPSK4 2024 22

CO-EXPOSURE OF $PM_{2.5}$ AND NOISE AMONG AUTOMOTIVE WORKERS AND THEIR CARDIOVASCULAR HEALTH STATUS AT A SELECTED AUTOMOTIVE MANUFACTURING INDUSTRY IN SELANGOR, MALAYSIA

ANEESAH AMANI BINTI SUFFIAN

DEPARTMENT OF ENVIRONMENTAL AND OCCUPATIONAL HEALTH

FACULTY OF MEDICINE AND HEALTH SCIENCES

UNIVERSITI PUTRA MALAYSIA

SERDANG, SELANGOR

2023/2024

CO-EXPOSURE OF $PM_{2.5}$ AND NOISE AMONG AUTOMOTIVE WORKERS AND THEIR CARDIOVASCULAR HEALTH STATUS AT A SELECTED AUTOMOTIVE MANUFACTURING INDUSTRY IN SELANGOR, MALAYSIA

BY

ANEESAH AMANI BINTI SUFFIAN

Thesis submitted in fulfilment of the requirement for the degree of Bachelor of Science in Environmental and Occupational Health with Honours from the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest gratitude to my supervisor, Dr. Nor Eliani Ezani, for patiently guiding me throughout my final year project journey and for not giving up on me whenever I feel discouraged to continue my FYP. I truly appreciate her since she had to sacrifice her time to check my manuscript, poster, and thesis in detail, even though she had many important things to settle with. I would also like to thank my co-supervisor, Dr. Nor Izah Ab Razak, for willingly teaching me the proper way to use the automatic digital sphygmomanometer and for teaching me about cardiovascular health status.

I am also very thankful to my mom, Haslinda Binti Abdullah, for her prayers and continuously encouraging me to finish this study, even when I feel like I am about to fail or am incapable of accomplishing it. Without her, I think I would not be able to finish this study. Additionally, I extend my appreciation to XXX Automotive Manufacturing Industry for allowing me to carry out my study and to the workers who willingly participated in this study. I would also like to thank my friends (Syamil, Engku, Aisyah Najihah, Amir, Wan Afif, Taqiyyah, Nisa, and Yasir) for always helping me during the collection of data at the factory as well as throughout my FYP journey. Last but not least, I want to thank my dear self for not giving up and continuing to finish this project even though you are late from others.

ABSTRACT

CO-EXPOSURE OF $PM_{2.5}$ AND NOISE AMONG AUTOMOTIVE WORKERS AND THEIR CARDIOVASCULAR HEALTH STATUS AT A SELECTED AUTOMOTIVE MANUFACTURING INDUSTRY IN SELANGOR, MALAYSIA

ANEESAH AMANI BINTI SUFFIAN

Introduction: Cardiovascular health can be affected by various factors, one of which is high blood pressure, which can be caused by acute exposure to loud noise above 85 decibels and exposure to high levels of fine particulate matter ($PM_{2.5}$) during working hours. To begin with, $PM_{2.5}$ is particulate matter with a diameter of 2.5 micrometres or less, while noise is an unwanted sound or a combination of sounds that can have a detrimental health effect on workers. These effects range from disruptions in cognitive processing to impairing mental and physical health, depending on the characteristics, intensity, and nature of the noise. The combined exposure to both of these factors can worsen the effects on our cardiovascular health, particularly regarding blood pressure and heart rate. **Objectives:** This study aims to assess the association between $PM_{2.5}$ and occupational noise exposure among automotive workers with their cardiovascular health status in a selected automotive manufacturing industry in Selangor, Malaysia. **Methodology:** This study was conducted at an automotive manufacturing factory located in Shah Alam Selangor, Malaysia, where the company mainly manufactures plastic products for many automotive industries. A set of questionnaires was distributed to 37 workers at the Painting line Block B Assembly at this factory in which were used to assess the worker's sociodemographic background, work characteristics, indoor air quality assessment (IAQ), noise exposure assessment, and the worker's cardiovascular health status. $PM_{2.5}$ DustTrak II Handheld Aerosol Monitor model 8523 ($\mu g/m^3$) and Sound Level Meter (SLM) were used to measure $PM_{2.5}$ and noise levels, respectively. The respondents' cardiovascular health status was also assessed using an automatic digital sphygmomanometer to measure their blood pressure levels (Systolic Blood Pressure, Diastolic Blood Pressure, and Pulse) for before and after their work. Sound Level Meters were also employed in this study to measure the background noise with the purpose of assessing the effects of polishing activity to the workers who worked near the work unit. All the measurements were taken from 8:00 a.m. until 5:00 p.m. on 5 non-consecutive working days. **Results and Discussion:** The median for $PM_{2.5}$ concentration recorded at the indoor polishing work unit exceeded the limit recommended by the National Ambient Air Quality Standard (NAAQS) and the World Health Organization (WHO), i.e., 53.6 $\mu g/m^3$. Contrarily, the median for noise level was found complied with the Department of Occupational Safety and Health (DOSH) limits, i.e., 78.5 dB(A). The association between these two variables was found to have a positive and moderate correlation ($r = 0.40$). The mean systolic blood pressure (SBP) was the only one to be found within the normal range for the pre-working measurements (121.5 ± 10.7), while the diastolic blood pressure (DBP) and Pulse rate were found to be slightly lower than their normal recommended value (70.8 mmHg ± 9.8 and 76.9 pulse/min ± 10.8 respectively). Conversely, for the post-working measurements, only the pulse was discovered to be within the normal range (80.0 ± 12.5) while SBP and DBP were below the normal value (116.7 mmHg ± 13.2 and 65.3mmHg ± 10.2). Our study found no association between the coexposure of $PM_{2.5}$

and noise level with the cardiovascular health status of the workers. **Conclusion:** The combined exposure of $PM_{2.5}$ and noise level does not affect the cardiovascular health status of the selected workers, suggesting that this study deserved further investigation by increase number of sample size, number of sampling days and conducted in different areas of automotive manufacturing department. Of these shall comprehend a thorough understanding concerning the co-exposure of particulate matter ($PM_{2.5}$) and noise on cardiovascular health status.

Keywords: Cardiovascular health status, particulate matter ($PM_{2.5}$), noise, automotive manufacturing workers, coexposure

ABSTRAK

PENDEDAHAN BERSAMA $PM_{2.5}$ DAN BUNYI DALAM KALANGAN PEKERJA AUTOMOTIF DAN STATUS KESIHATAN KARDIOVASKULAR MEREKA DI INDUSTRI PEMBUATAN AUTOMOTIF TERPILIH DI SELANGOR, MALAYSIA.

ANEESAH AMANI BINTI SUFFIAN

Pengenalan: Kesihatan kardiovaskular boleh dipengaruhi oleh pelbagai faktor, salah satunya adalah tekanan darah tinggi, yang boleh disebabkan oleh pendedahan akut kepada bunyi bising melebihi 85 desibel dan pendedahan kepada bahan zarah halus ($PM_{2.5}$) tahap tinggi semasa waktu bekerja. Sebagai permulaan, $PM_{2.5}$ ialah bahan zarah dengan diameter 2.5 mikrometer atau kurang, manakala bunyi bising ialah bunyi yang tidak diingini atau gabungan bunyi yang boleh memberi kesan kesihatan yang memudaratkan kepada pekerja. Kesan ini terdiri daripada gangguan dalam pemprosesan kognitif kepada menjejaskan kesihatan mental dan fizikal, bergantung pada ciri, keamatan dan sifat bunyi. Pendedahan gabungan kepada kedua-dua faktor ini boleh memburukkan lagi kesan pada kesihatan kardiovaskular kita, terutamanya mengenai tekanan darah dan kadar denyutan jantung. **Objektif:** Kajian ini bertujuan untuk menilai perkaitan antara $PM_{2.5}$ dan pendedahan bunyi bising di kalangan pekerja automotif dengan status kesihatan kardiovaskular mereka dalam industri pembuatan automotif terpilih di Selangor, Malaysia. **Metodologi:** Kajian ini dijalankan di sebuah kilang pembuatan automotif yang terletak di Shah Alam Selangor, Malaysia, di mana syarikat itu kebanyakannya mengeluarkan produk plastik untuk banyak industri automotif. Satu set soal selidik telah diedarkan kepada 37 pekerja di *'Painting line Block B Assembly'* di kilang ini yang digunakan untuk menilai latar belakang sosiodemografi pekerja, ciri kerja, penilaian kualiti udara dalaman (IAQ), penilaian pendedahan bunyi dan kesihatan kardiovaskular pekerja. status. *$PM_{2.5}$ DustTrak II Handheld Aerosol Monitor model 8523* (µg/m^3) dan *Sound Level Meter* (SLM) masing-masing digunakan untuk mengukur $PM_{2.5}$ dan tahap bunyi bising. Status kesihatan kardiovaskular responden juga dinilai menggunakan sphygmomanometer digital automatik untuk mengukur tahap tekanan darah mereka (Tekanan Darah Sistolik, Tekanan Darah Diastolik dan Nadi) sebelum dan selepas bekerja. SLM juga digunakan dalam kajian ini untuk mengukur bunyi bising latar belakang dengan tujuan menilai kesan aktiviti menggilap kepada pekerja yang bekerja berhampiran unit kerja. Semua pengukuran telah diambil dari 8:00 pagi hingga 5:00 petang pada 5 hari bekerja tidak berturut. **Keputusan dan Perbincangan:** Median untuk kepekatan $PM_{2.5}$ yang direkodkan pada unit kerja penggilap (dalaman) melebihi had yang disyorkan oleh Piawaian Kualiti Udara Ambien Kebangsaan (NAAQS) dan Pertubuhan Kesihatan Sedunia (WHO), iaitu, 53.6 µg/m^3. Sebaliknya, median untuk tahap hingar didapati mematuhi had Jabatan Keselamatan dan Kesihatan Pekerjaan (DOSH), iaitu, 78.5 dB(A). Perkaitan antara kedua-dua pembolehubah ini didapati mempunyai korelasi positif dan sederhana ($r = 0.40$). Purata tekanan darah sistolik (SBP) adalah satu-satunya yang ditemui dalam julat normal untuk pengukuran sebelum bekerja (121.5 ± 10.7), manakala tekanan darah diastolik (DBP) dan kadar Nadi didapati lebih rendah sedikit daripada mereka. nilai biasa yang disyorkan (masing-masing 70.8 mmHg ± 9.8 dan 76.9 nadi/min ± 10.8). Sebaliknya, untuk pengukuran selepas kerja, hanya nadi didapati berada dalam julat normal (80.0 ± 12.5) manakala SBP dan DBP berada di bawah nilai normal (116.7 mmHg ± 13.2 dan 65.3mmHg ± 10.2). Kajian kami mendapati tiada perkaitan antara pendedahan bersama $PM_{2.5}$ dan tahap hingar dengan status kesihatan kardiovaskular pekerja. **Kesimpulan:** Gabungan pendedahan $PM_{2.5}$ dan tahap bunyi bising tidak menjejaskan status kesihatan kardiovaskular pekerja terpilih, menunjukkan bahawa kajian ini patut disiasat lebih lanjut dengan menambah bilangan saiz sampel, bilangan hari persampelan dan dijalankan di pelbagai bidang pembuatan automotif. bahagian. Daripada ini akan memahami pemahaman yang menyeluruh mengenai pendedahan bersama bahan zarahan ($PM_{2.5}$) dan bunyi pada status kesihatan kardiovaskular.

Kata kunci: Status kesihatan kardiovaskular, bahan zarahan ($PM_{2.5}$), bunyi bising, pekerja pembuatan automotif, pendedahan bersama

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

$PM_{2.5}$	Particulate Matter ($PM_{2.5}$)
WHO	World Health Organization
NAAQS	National Ambient Air Quality Standard
DOSH	Department of Occupational Safety and Health
NIHL	Noise-Induced Hearing Loss
CVD	Cardiovascular Diseases
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
SLM	Sound Level Meter

CHAPTER 1

INTRODUCTION

1.1 Study background

The recent expansion of Malaysia's manufacturing industrial sector is a result of rising consumer demand, technological advancement, and competitiveness, especially in the wake of the 15^{th} general election. Due to the complexity and specialisation required in the production processes to ensure optimal efficiency and the highest standard of product quality, it has raised the demand for an enormous number of qualified workers in most of the manufacturing industry, particularly in the automotive manufacturing industry. This can be proven from a statistical report by the Statista research department (2022), where there were more than 25,000 people employed in 2022 in the manufacturing of motor vehicles in Malaysia, which shows an increment from the preceding year.

This particular industry entails niche work processes in the production of a solid car, among which are stamping, sheet metal, painting, and assembly (Automotive Process, 2019). These work processes pose numerous occupational hazards, putting automotive manufacturing workers at high risk of various occupational hazards, especially those who work in an enclosed working area and work overtime. These hazards encompass physical, chemical, and biological hazards, as well as psychosocial and ergonomic risk factors, with workers being exposed to these hazards depending on the nature of the occupational setting that they work in. However, this study will be primarily focused on chemical and physical hazards extensively, specifically emphasizing on fine particulate matter ($PM_{2.5}$) and noise respectively, in the selected automotive manufacturing industry.

$PM_{2.5}$ and noise are typically regarded as "silent killers" due to their capability to cause serious and irreversible health conditions in individuals who experience prolonged and substantial levels of exposure (Basith et al., 2022; Chen et al., 2023; Recio et al., 2016; Wang et al., 2022). Furthermore, since these hazards cannot be seen with the naked eye and due to the perception of low-risk to $PM_{2.5}$ and noise, employers and employees tend to overlook the safe work practices concerning indoor air pollutants as well as noise and the threat that these hazards can bring upon the workers.

In the automotive manufacturing industry, punching and casting work units have the highest degrees of noise hazards, exceeding the recommended standard by 65% and 50%, respectively (Wang et al., 2015), which means most of the workers are exposed to noise levels above 85 dBA during their working hours. Workers who are frequently exposed to noise levels above 85 dBA are more likely to experience a wide range of health issues both in the short and long term, depending on the frequency and duration of exposure (Themann & Masterson, 2019). Short-term exposure to noise can lead to a temporary threshold shift, temporary tinnitus, difficulty to comprehend speech amidst noisy surroundings, noise-induced hearing loss, and acute cardiovascular health effects. On the other hand, long-term exposure can lead to permanent hearing loss, permanent tinnitus, and chronic cardiovascular health effects. The Department of Statistics Malaysia reported that as of 2021, there were a total of 5,289 confirmed cases of occupational disease, with the manufacturing industry accounting for the majority of cases (3,383) and occupational noise-induced hearing disorder being the leading cause of the disease (3,648) (Department of Statistics Malaysia Official Portal, n.d). In addition, The Star (2022) disclosed that 1,273 cases of occupational noise-induced hearing loss (NIHL) were reported, making up 62.3% of all reported occupational disease cases during the first five months of 2022. These data unequivocally illustrate that noise is a prevailing and serious occupational hazard among manufacturing workers.

As these workers are exposed to noise, at the same time they can also be exposed to $PM_{2.5}$, which potentially come from various working processes such as casting, machining, and assembly (D'Arcy et al., 2016). Moreover, a study conducted by Dallos (2019) revealed that the process of welding, machining, cutting, and grinding in the automotive manufacturing sector also releases $PM_{2.5}$. Nguyen et al. (2018) also stated that these workers may be simultaneously exposed to multiple types of occupational hazards from the same or even different types of hazards, which could exacerbate the health effect. There are few studies that could support the aforementioned claim; for instance, Sliwinska-Kowalska et al. (2004) concluded from their study that the co-exposure of chemicals (organic solvents) and noise has an additive detrimental effect on the auditory organs compared to noise impacts alone, with the occurrence of hearing loss exhibiting a significant increase with the odds ratio (OR) approaching almost threefold in the noise-only group and nearly fivefold in the noise and solvent group. Apart from that, a study conducted by Guha & Gokhale (2023) discovered that the combined effect of $PM_{2.5}$ and noise has a substantial impact on employees' health in traffic corridors in terms of cardiovascular impact.

1.2 Problem Statement

Cardiovascular diseases are the most prevalent cause of death worldwide, with an approximately 17.9 million fatalities in 2019, accounting for 32% of all global deaths where heart attack and stroke were responsible for 85% of these deaths (WHO, 2021). Furthermore, there are extensive studies that address the effects of cardiovascular diseases that can be caused by the exposure to occupational noise as well as $PM_{2.5}$. Rabiei et al. (2021) discovered from their study that occupational noise increased the chances of developing cardiovascular disease by 28%. Their study also stated that the noise exposure at work still has a substantial impact on cardiovascular health status, such as elevated blood pressure, even though it is generally below the permitted limit for hearing diseases. This demonstrates that even exposure to lower than 85 dB(A) already exhibits signs of cardiovascular problems; therefore, exposure to higher than 85 dB(A) will have even more detrimental health effects, especially with long-term exposure. As an example, workers in metal manufacturing who were exposed to noise levels exceeding 85 dB(A) developed elevated blood pressure, with the odds of having prehypertension increased with years of work experience, advanced age, smoking, and alcohol consumption (Melese et al., 2023).

In a study conducted by Li et al. (2019), it was also mentioned in their research results that industrial workers who exposed to higher than 85 dB(A) are more prevalent in having hypertension and hearing difficulty where hypertension involves with activation of the hypothalamic-pituitary-adrenal axis (main stress response system) and sympathetic nervous system. Other than that, Munzel,T. et al. (2018) discovered from their studies that noise can facilitate the development of CVD as it has an indirect contribution to cardiovascular disease through disrupted sleep, chronic stress, and associated risk factors like elevated blood pressure and inflammation. Chronic stress and noise-induced annoyance contribute to cardiovascular risk factors such as increased blood pressure, glucose levels, blood viscosity, blood lipids, and activation of blood coagulation. Even though there is numerous research that shows an association between noise and cardiovascular disease, there are also few studies that contrast those findings. A cross-sectional study carried out by Zamanian et al. (2013) reported that there were no significant changes in blood pressure and heart rate in industrial workers after acute exposure to noise levels of 85, 95, and 105 dB(A). This inconsistency could be attributed to a variety of factors, including differences in study design, demographic characteristics, noise assessment methodologies, confounding variables, and even due to different usage of personal protective equipment among workers (Li et al., 2019). As a result, there is a knowledge gap in understanding the true relationship between noise exposure and cardiovascular health status or outcomes.

Particulate matter, on the other hand, emerges as a significant contributor to adverse health effects, most notably cardiovascular diseases (CVDs), with finer particles playing a critical role in triggering cardiovascular events as they have a larger reactive surface area (Basith et al., 2022). Furthermore, it can aggravate the effects on human health, particularly among vulnerable individuals, such as those with existing health problems (Ain & Qamar, 2021). In the United States alone, about 1 million people are at risk of developing health problems as a result of poor indoor air quality (IAQ) in the automotive manufacturing industry. In fact, there are abundant working processes in the manufacturing industry that could potentially expose the workers to particulate matter $PM_{2.5}$, which are dry machining cast iron, AI Diecast, body shop welding, carburizing furnace, and iron foundry (melt-pour), which means that those workers working in the automotive manufacturing industry could be potentially exposed to high $PM_{2.5}$, especially if they are not wearing proper personal protective equipment and are not adhering to the safe work system established in the company.

Furthermore, in addition to the preceding problems, there are also numerous separate studies (Chuang et al., 2020; Chang et al., 2015; Du et al., 2016) that have established a strong link between noise and cardiovascular health status, as well as an association between $PM_{2.5}$ and workers' cardiovascular health status. However, there are very limited studies that emphasise the impact of cardiovascular health status in the context of co-exposure to these parameters ($PM_{2.5}$ and noise), particularly among automotive manufacturing workers. (Guha & Gokhale, 2023; Li et al., 2019).

1.3 Study Justification

Conducting an in-depth study regarding the co-exposure of $PM_{2.5}$ and noise among automotive manufacturing workers while assessing their cardiovascular health status as the effect of the co-exposure to both hazards will allow the researcher to have a comprehensive understanding of the combined effects on the worker's cardiovascular health status (Ren et al., 2016). On top of that, it is undeniable that noise and indoor air pollutants, especially $PM_{2.5}$, coexist in manufacturing industrial environments, and it has been proven through the mentioned studies that exposure to $PM_{2.5}$ and noise have cardiovascular effects individually; thus, assessing one indicator or factor at a time may significantly lead to an underestimation of health risk since noise and air pollution have apparent health effects on the cardiovascular system.

Apart from that, most of the work processes that emit noise and $PM_{2.5}$, such as welding, grinding, machining, and cutting, are among the everyday work processes needed in the industry, inevitably exposing the workers to substantial levels of $PM_{2.5}$ and noise throughout their working hours. This signifies the necessity of assessing the combined effects of $PM_{2.5}$ and noise on their cardiovascular health status, as they have been discovered to have a strong association for their individual effects alone. Moreover, there are limited studies that comprehensively research concerning the effects of combined exposure to $PM_{2.5}$ and noise on the cardiovascular health status of automotive manufacturing workers, as it was ventured more to traffic-related areas (Biel et al., 2020; Guha & Gokhale, 2023; Moshammer et al., 2019).

In order to efficiently comprehend the importance of associating $PM_{2.5}$ and noise exposure with cardiovascular health in the context of this research study, it is necessary to grasp the key terms concisely. First and foremost, $PM_{2.5}$ is classified as fine particulate matter that has the capability to penetrate deep into the human's lung, which then can cause damage to the alveoli that reside within the lungs and eventually cause respiratory issues. The concerning part is that it can even affect the bloodstream, triggering other health issues such as coughing and shortness of breath. Next, according to Munzel et al. (2019), continuous exposure to high levels of noise could disrupt the hormone balance in the body, which in the end will cause inflammation of blood vessels and subsequently increase the risk of having cardiovascular risk factors. On the other hand, cardiovascular health represents the overall wellbeing of the circulatory system as well as the heart, which can be affected by many factors, including $PM_{2.5}$ and noise in particular. These detrimental effects posed by both individual and combined exposure to $PM_{2.5}$ and noise were also stated by these studies (Chuang et al., 2020; Guha & Gokhale, 2023; Li et al., 2019; Yang et al., 2020). Hence, the importance of studying the co-exposure of $PM_{2.5}$ and noise to the worker's cardiovascular health is crucial as it can exacerbate the cardiovascular health if being simultaneously exposed to high levels of $PM_{2.5}$ and noise. Besides that, focusing on the interconnection of working environment components and their effect on human well-being is crucial because it could prevent health risks to some extent.

Hence, this study aimed to assess the association between $PM_{2.5}$ and noise levels among automotive workers and their cardiovascular health status, which will contribute to the extensive knowledge among researchers as well as the public on the impact of combined exposure to $PM_{2.5}$ and noise among workers; therefore, it justifies the need and importance of conducting this study. Moreover, understanding the publicly unfamiliar factors that have an impact on cardiovascular health status is essential in developing preventive measures that will also provide some insight that could notify targeted interventions and possibly reduce the prevalence of cardiovascular diseases in forthcoming years.

1.4 Research Question

I. What is the distribution of socio-demographic factors and work characteristics of the automotive workers?

II. Is there any significance difference between the levels of $PM_{2.5}$ and noise with their recommended levels

III. Is there any association between $PM_{2.5}$ and noise exposure?

IV. What is the cardiovascular health status of the selected automotive workers in an automotive manufacturing industry in Selangor, Malaysia?

V. Does the co-exposure of noise and $PM_{2.5}$ cause cardiovascular health effects among selected workers at the selected automotive manufacturing industry?

1.5 Research Objectives

1.5.1 General Objectives

This study aimed to assess the association between particulate matter ($PM_{2.5}$) and occupational noise among automotive workers and their cardiovascular health status in a selected automotive manufacturing industry in Selangor, Malaysia.

1.5.2 Specific Objectives

I. To determine the socio-demographics and work characteristics of the automotive workers .

II. To determine the levels of particulate matter ($PM_{2.5}$) and noise in a selected automotive manufacturing industry in Selangor, Malaysia

III. To determine the association between $PM_{2.5}$ and noise exposure

IV. To assess the cardiovascular health status among selected workers in a selected automotive manufacturing industry in Selangor, Malaysia.

V. To determine the association of cardiovascular health effects among selected workers with the co-exposure of $PM_{2.5}$ and noise.

1.6 Research Hypothesis

There is an association between the co-exposure of particulate matter ($PM_{2.5}$) and noise among automotive workers and their cardiovascular health status at the selected automotive manufacturing industry.

1.7 Variables

1) Independent variable

There are two independent variables in this study, which are particulate matter ($PM_{2.5}$) and noise. The reason these variables are selected is because one of the work processes in the selected automotive manufacturing industry simultaneously emits $PM_{2.5}$ and generates noise.

2) Dependent variable

The dependent variable for this study is cardiovascular health status of the selected workers in the selected automotive manufacturing industry due to the co-exposure of $PM_{2.5}$ and noise. The cardiovascular health status of the workers can be assessed through two methods which are by conducting simple medical check-ups and through distributing questionnaires. For the basic medical health examination, blood pressure and heart rate of the workers were examined before and after work.

1.8 Definition of Terms

1. Particulate Matter ($PM_{2.5}$)

Conceptual definition: Particulate matter ($PM_{2.5}$) is a fine inhalable particles having a diameter of 2.5 micrometres or smaller that usually suspend in the air as a mixture of solid particles and liquid droplets in the air (US EPA, 2023)

Operational definition: The level of $PM_{2.5}$ in a selected automotive manufacturing industry will be measured using DustTrak II Handheld Aerosol model 8523, where its brand, model, and country of origin are TSI, AM520, and the United States of America (USA), respectively. The practice of utilizing DustTrak to measure the exposure of mining workers to $PM_{2.5}$ was also implemented in a study conducted by Huang et al. (2019).

2. Occupational noise

Conceptual definition: Occupational noise is defined as an unwanted sound or a combination of sounds that have detrimental health effects on the workers, ranging from disruptions to cognitive processing to impairing mental and physical health, depending on its characteristics, intensity, and nature.

Operational definition: According to few studies, Sound Level meter (SLM) type 1 will be used to assess the exposure of the workers to noise. The equipment will be positioned 1.5 meters above the ground and one meter away from the noise source in the automotive manufacturing industry (Alnabih et al., 2021; Wojtyto et al., 2021).

3. Cardiovascular health status

Conceptual definition: According to Krietsch (2022), cardiovascular health refers to the well-being of the heart and blood vessels, where good cardiovascular health indicates that the person's heart, blood vessels, and circulatory system are in good shape and are capable of carrying out their functions effectively. Poor cardiovascular health status on the other hand, suggests the opposite condition of good cardiovascular health status in which it leads to an increased risk of the person having cardiovascular disease. Cardiovascular disease (CVD) pertains to conditions that affect the heart or blood vessels and is divided into four major types, which are coronary artery disease (CAD), cerebrovascular disease, aortic atherosclerosis, and peripheral artery disease (PAD), and there are extensively various diseases within each of these major types (Lopez et al., 2022). The World Health Organisation (2021) stated that over 10 million deaths worldwide were reported annually, where hypertension (high blood pressure) is the prominent risk factor for CVD.

Operational definition: The selected workers' health effects due to the co-exposure of noise and particulate matter ($PM_{2.5}$) will be assessed by using a modified set of questionnaires retrieved from a few related studies and the Industry Code of Practice (ICOP), which are from the ICOP For Management of Occupational Noise Exposure and Hearing Conservation (2019), the ICOP on Indoor Air Quality (IAQ) (2010), the health assessment of noise exposure questionnaire retrieved from University of California, Berkeley, Guha & Gokhale (2023) study and the Malaysia HEalth and WellBeing Assessment (MyHEBAT) Study Protocol from Firus Khan et al. (2022). An automatic digital sphygmomanometer will also be used to carry out basic health check-ups such as measurements of blood pressure and pulse among selected automotive manufacturing workers (Guha & Gokhale, 2023) to give a more significant result. Face-to-face questionnaire surveys and health check-ups will be carried out on working days from 8:00 a.m. to 5:00 p.m.

4. Automotive manufacturing workers

Conceptual definition: Automotive manufacturing workers are those who work in "the parts production and assembly plants of automobile manufacturers. Their labour involves work from the smallest part to the completed automobiles. Automotive industry workers read specifications, design parts, build, maintain, and operate machinery and tools used to produce parts, and assemble the automobiles" (Firsthand, n.d.).

1.9 Conceptual Framework

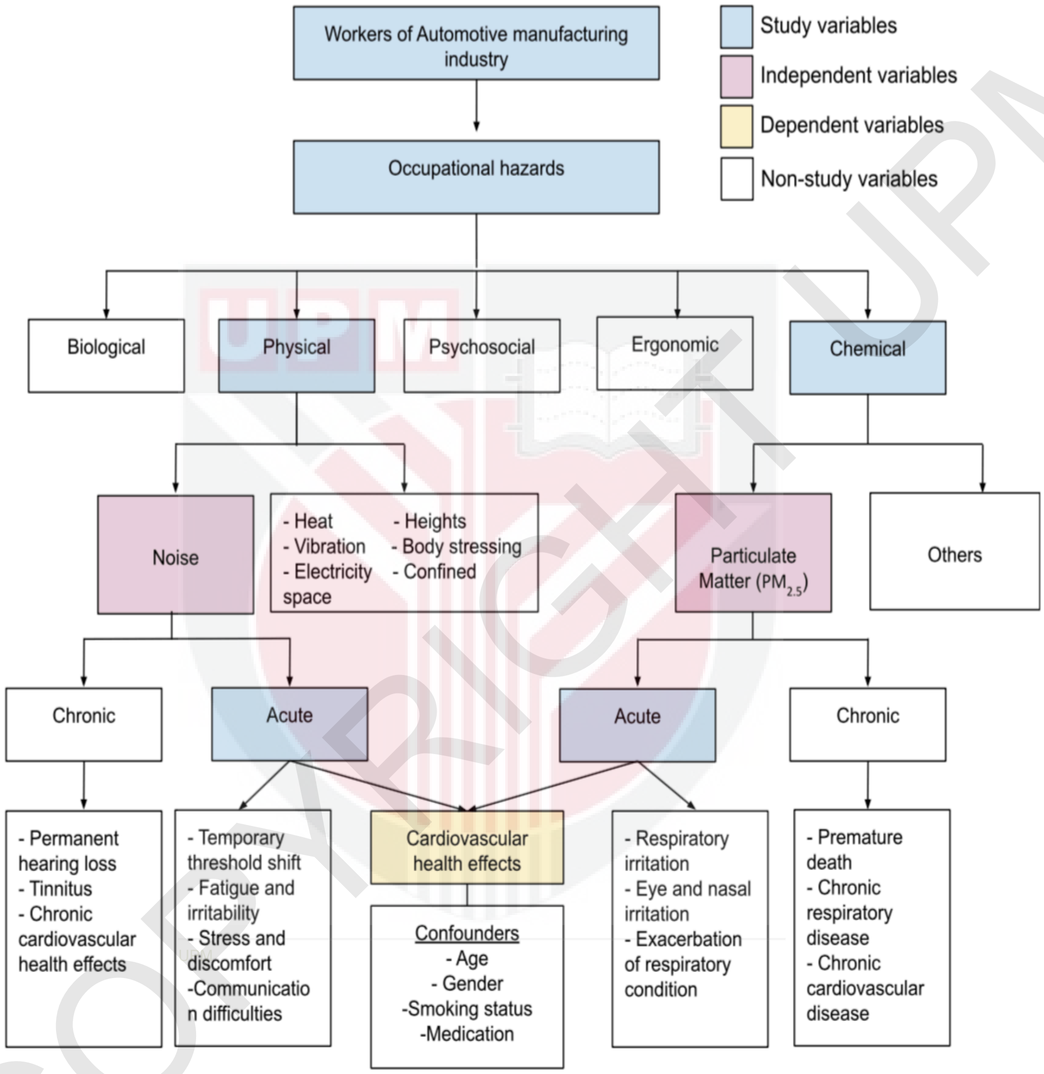


Figure 1.1: Conceptual Framework

CHAPTER 2

LITERATURE REVIEW

This part of the thesis encompasses a thorough exploration, discussion, and analysis of components that are interconnected within the research area, which are mainly pertaining to the scientific understanding of how the combined effects of $PM_{2.5}$ and noise exposure might influence one's cardiovascular health status.

2.1 Sources of $PM_{2.5}$ in Automotive Manufacturing Industry

Sources of $PM_{2.5}$ in the automotive industry can vary depending on which department or work unit the workers work in. For instance, a study conducted by Mustaffa & Megat (2018) found that the workers who worked at welding activities at the fitting line of an automotive industry had the highest exposure to $PM_{2.5}$. In another study that studied the $PM_{2.5}$ exposure among mechanics at a motor vehicle testing centre in Jakarta, they were found to be exposed to $PM_{2.5}$ levels exceeding the WHO IAQ guidelines with a concentration level of 149.01 μm/m^3, where the high level of $PM_{2.5}$ levels was contributed by the exhaust emissions from motor vehicles during testing (Rizky et al., 2016). Other automotive manufacturing activities such as machining, cutting, and grinding were also found to emit $PM_{2.5}$ (Dallos, 2019). However, there are insufficient studies that have studied the automotive workers' exposure to $PM_{2.5}$ within their different work processes, especially in polishing work activities.

2.2 Sources of Noise in Automotive Manufacturing Industry

Automotive manufacturing industry encompasses various work unit each of which have their specific functions that contribute to the smooth and efficient production of the products, and the extent of exposure to high levels of noise can be vary depending on the specific processes or job tasks involved where the risk of occupational noise exposure in any work unit is possible; however, there are some workers that will encounter a greater probability to be exposed to higher noise levels compared to others (Zulkefli et al., 2017). This difference occurs due to several factors including specific job tasks that they operate, types of equipment used and even the environment of the workplace itself.

Based on a study conducted by Wang et al. (2015), it is found from the studied location (automotive manufacturing industry) that punching and casting work units present the highest levels of occupational noise risk in which it exceeded the recommended limit of noise provided in the Occupational Safety and Health (Noise Exposure) Regulations 2019 where it specifically state that the worker shall not be exposed to noise level exceeded 85 dBA. However it exceeded the limit by 65% and 50% respectively. Chen et al., (2019) stated that the personal noise exposure measurement carried out among workers in an automotive manufacturing industry in China transcend 62.53% of the noise limit (85 dBA) where the specific work unit that poses this threat is metal cutting, stamping, welding, grinding, assembly, plastic molding, forging, and surface treatment.

2.3 $PM_{2.5}$ and Its Effects On Cardiovascular Health Status.

$PM_{2.5}$ refers to a particulate matter with a diameter of 2.5 micrometer or less which can directly or indirectly affect our cardiovascular systems (Feng et al., 2023). Unlike PM_{10} that could only enter up until the upper respiratory tract, $PM_{2.5}$ has the ability to penetrate deep into our lungs and even deposit in the terminal bronchioles and alveoli mainly due to its small size characteristics which eventually can enter the circulatory system through the gas-blood barrier (Yang et al., 2020). This is where the direct pathway begins as it has a direct action to our cardiovascular system through blood circulation. Examples of direct effects are the production of reactive oxygen species, ion channel dysfunction, and vascular dysfunction. $PM_{2.5}$ has the tendency to cause detrimental health effects as it enters our bloodstream. One of the key damaging effects is its ability to produce cytotoxic substances known as reactive oxygen species (ROS) with hydrogen peroxide and superoxide being the most crucial cytotoxic effects of $PM_{2.5}$ (Nelin et al., 2012). Other studies' findings also found the strong association between $PM_{2.5}$ exposure with the metabolic dysregulation and increased ROS. These substances are generated through chemical reactions between organic hydrocarbons and transition metals present in Particulate matter. Based on research conducted by

Favero et. (1995), they found that hydrogen peroxide could initiate the release of calcium ion (Ca2+) from sarcoplasmic reticulum located in the skeletal muscles, hence lead to imbalance in calcium level which could trigger myocardial dysfunction such as arrhythmias and contractile dysfunction (Reid et al., 2017).

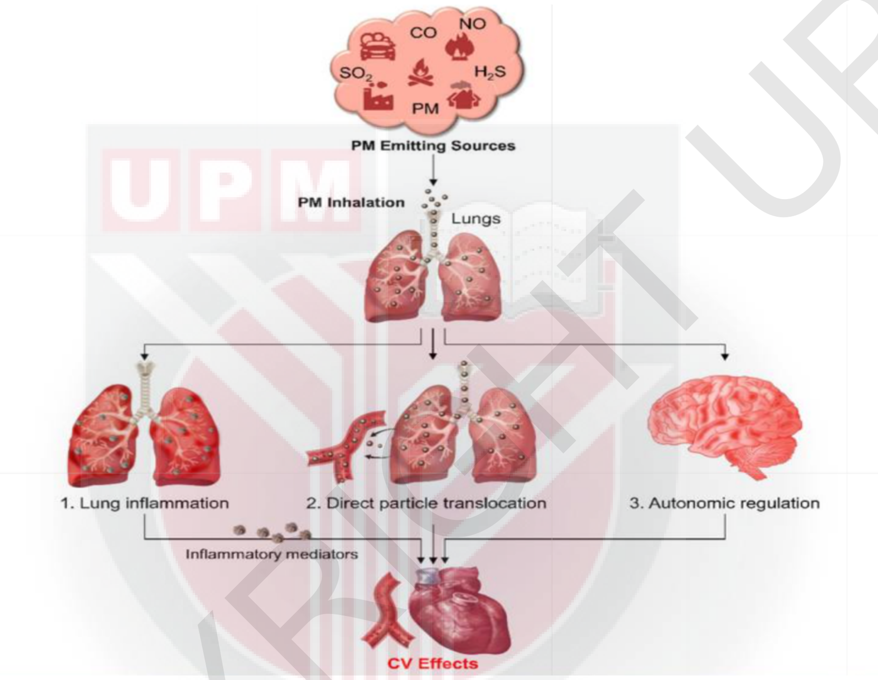


Figure 2.1: Summary of the Pathway on How $PM_{2.5}$ Affects the Cardiovascular System (Source : Basith et al., 2022)

2.4 Noise and its Effects on Cardiovascular Health Status.

Noise that indicated as unpleasant, unwanted, and disturbing noise is divided into three types which are steady, fluctuating, and impulse/impact noise. According to the ICOP, 2019, steady noise is reasonably constant and the meter reading on slow response does not vary by more than 3 decibels. On the other hand, fluctuating noise is considered when the noise levels are not stable where the meter reading on slow response fluctuates with a decibel range between 3 and 10. Last but not least, impulse noise is defined as a sudden loud noise that greatly differs from the typical noise levels encountered in normal workplaces. Identifying types of noise is very crucial in the process of generating accurate analysis during data interpretation. These descriptions of noise can also be illustrated through a graph which can be seen from below:

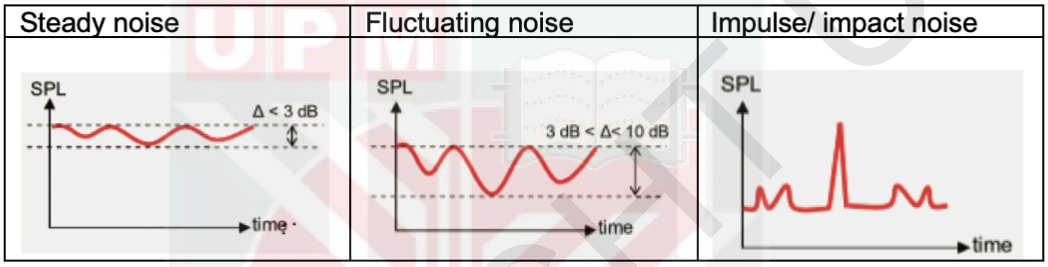


Figure 2.2: Types of Noise (Source : DOSH, 2019)

Cardiovascular health effects among automotive manufacturing workers caused by noise could occur as it initiates stress response by increasing the release of stress hormones (cortisol, adrenaline, and noradrenaline) (Munzel et al., 2018). Prolonged elevation of these adrenaline could cause an imbalance between the body's ability to neutralize reactive oxygen species (ROS) which subsequently will increase vascular oxidative stress, inciting vascular dysfunction such as reduces vasodilation and increases vasoconstriction, proliferation as well as inflammation leading to cardiovascular risk factors like increased blood pressure, glucose levels, blood viscosity and blood lipids, and activation of blood coagulation. These situations will give rise to the manifestation of cardiovascular diseases such as hypertension, heart failure, coronary artery disease, etc.

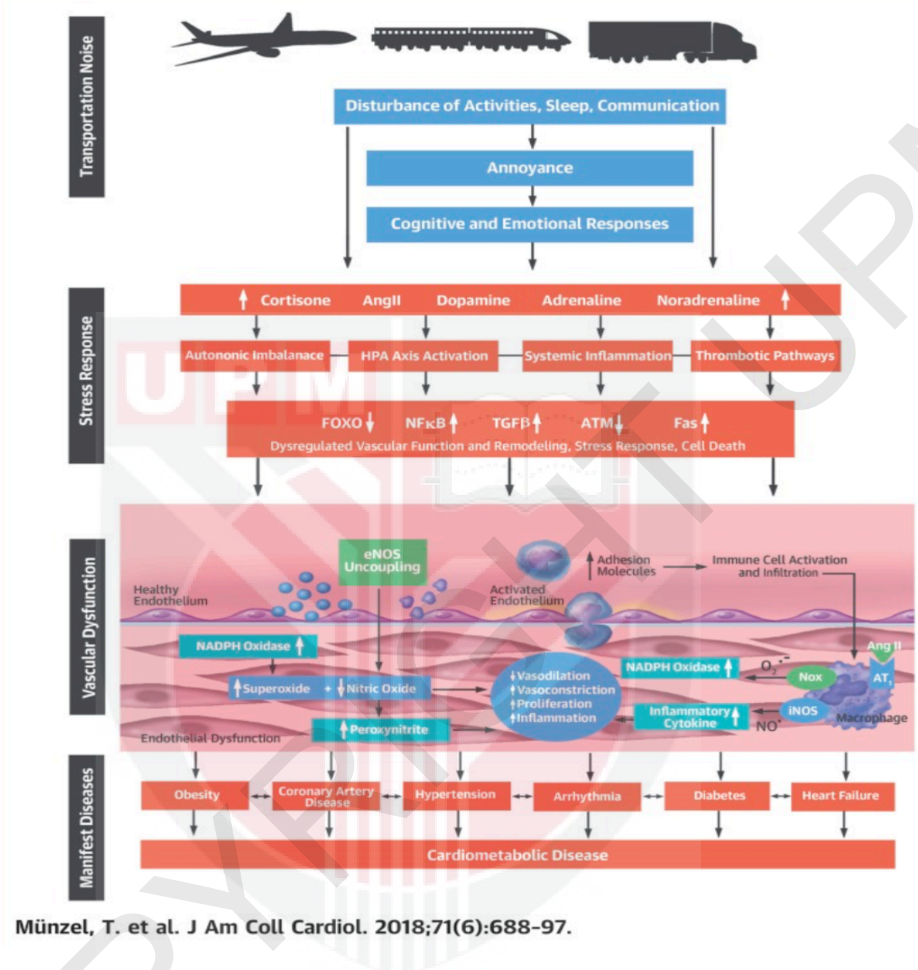


Figure 2.3: Summary of the Pathway on How Noise Exposure Affects the Cardiovascular System (Source : Munzel, T. et al., 2018)

2.5 Co-exposure of $PM_{2.5}$ and Noise on Cardiovascular Diseases

As been mentioned in chapter 1 before, $PM_{2.5}$ and noise can coexist in an environment, and the combined effects of them towards cardiovascular health status were studied in several studies but in a different settings, mainly on traffic related settings. For instance, a study that investigates the short-term impact of fine particulate matter and noise found that their those who participates in their study experience increase of blood pressure after 24 hours, where the increase of the blood pressure were due to noise and particulate matter from traffic (Chang et al., 2015)

2.6 Selection of Instruments

2.6.1 Questionnaire

It is crucial to incorporate a questionnaire with specific questions regarding to noise, particulate matter ($PM_{2.5}$), and cardiovascular disease. A certain modification that aligns with the research objectives of this study also ought to be included, as it will significantly assist the researcher in obtaining specific and distinct information, thereby reducing the risk of having participants that fall under the exclusion criteria. For illustration, in a study conducted by Chang et al. (2015), they used a standardized questionnaire to determine the individual or combined effects of exposure to noise, $PM_{2.5}$, and NOx. They applied a standardized questionnaire, which led to a reduction in participants in their study from 69 to 66 students as the remaining three students have hypertension, which if these students were to be included in the study, it will interfere with the study outcome (Patino & Ferreira, 2018).

As for the selection of questions to be included in the questionnaire, they were taken from credible sources and previous studies to ensure the highest level of credibility of the data that can address these studies. For example, part A of the questionnaire consists of questions that are related to the respondent's personal information, such as age, gender, nationality, work characteristics, weight, height, and smoking status, where such information can help the researcher to an extent of having a basic understanding of their participants and for better interpretation and analysis of the data. These questions were integrated into most of the studies, among them are (Chen et al., 2015; Guha & Gokhale, 2023; Luna-Carrascal et al., 2023).

2.6.2 Sound Level Meter Type 1 (SOLO, 01 dB, USA)

In research performed by Alagapan et al. (2019), which focused on assessing the contribution of machines used in a spice manufacturing factory towards the worker's exposure to high levels of noise in the workplace, a Type 1 Sound Level Meter (SLM) was employed to measure the background noise of each workstation with the purpose of obtaining a clear noise mapping in favour of a detailed and visual representation of noise level in a specific location. Apart from that, SLM type 1 is the commonly used when it comes to field measurement rather than SLM type 2 as it has more precision in measurement compared to SLM type 2 (OSHA Technical manual, n.d.). This justifies the rationale behind the selection of this instrument to be included in this study.

2.6.3 DustTrak II Handheld Aerosol Monitor (TSI, AM520, USA)

DustTrak has the capability in giving a real-time aerosol mass concentration reading by employing light-scattering laser photometer method. It was placed on a flat surface as near as feasible to the polishing work unit station in order to retrieve the representative $PM_{2.5}$ exposure level of the workers. On the other hand, it was also used by Luna-Carrascal et al. (2023) with the purpose of associating the exposure levels of $PM_{2.5}$ with the components in blood and urine samples.

2.6.4 Automatic Digital Sphygmomanometer

Guha & Gokhale (2023) utilised an automatic digital sphygmomanometer in their study to measure the blood pressure and heart rate of two groups of workers that work in different environments which are office workers and vendors, where the measurement take place before and after being exposed to both noise and $PM_{2.5}$. Another study also used this particular equipment to measure the children's blood pressure due to the exposure of $PM_{2.5}$ (Liang et al., 2022). Based on both of the studies, it is evident, automatic digital sphygmomanometer is the best instrument to be used to measure blood pressure as it has the lowest risk in encountering human error compared to manual and mercury sphygmomanometer (Civil,2022).

2.7 Limitation of Previous Study

For the purpose of obtaining an insight into the importance and necessity of carrying out this study, there are a few limitations as well as recommendations from previous research regarding the relevancy of this study topic that shall be taken into account. A study executed by Chang et al. (2015) mentioned the need to perform studies that emphasise that future epidemiological studies should consider the interactive effects of co-exposure to noise and air pollutants to investigate the association between individual exposure and the development of cardiovascular disease. Another study also supported the statement of the previous study, which mentioned in the discussion part that a more extensive understanding could be obtainable if both noise exposure and air pollution were studied simultaneously since the study only investigated the individual effects on cardiovascular health.

CHAPTER 3

METHODOLOGY

3.1 Study Design

For the purpose of this research, a quantitative study was employed, as it involved objective measurements such as the personal exposure measurement of $PM_{2.5}$ and noise level among selected workers of XXX automotive manufacturing industry by using DustTrak and SLM respectively. Apart from that, this research also involved the use of statistical analysis in which to analyse the collected data to determine the significance difference for the co-exposure of $PM_{2.5}$ and noise with cardiovascular health effects among selected automotive manufacturing workers.

This was a cross-sectional study that aimed to assess the co-exposure of $PM_{2.5}$ and noise among workers and to determine whether the cardiovascular health effects of XXX automotive manufacturing industry workers are due to the co-exposure of $PM_{2.5}$ and noise. According to Setia (2016), cross-sectional studies are designed for studies aiming to determine the outcome as a result of exposure; therefore, this study was best conducted as a cross-sectional study.

3.2 Study Location

This study was conducted at Painting Line Block B Assembly of XXX Automotive Manufacturing Malaysia Sdn. Bhd. This manufacturing plant is located in Shah Alam, Selangor, specifically at Lot 75A & 76, Jalan Sementa 27/91 Section 27, Shah Alam, 40000 Selangor Malaysia. XXX have been manufacturing plastic products with the highest quality for numerous renowned local and global automotive industries for example, PROTON, Perodua, Volkswagen, and Toyota. Among the main production processes and services available are precision plastic injection moulding, painting, assembly, laser cutting, blow moulding, vacuum forming, and electroplating in which these particular operation lead to variety types of product which are bumper module, instrument panel assy module, door module, pillars, chrome parts as well as seat compartments. Figure 3.1 illustrates the location of the company on maps.

Figure 3.1: Satellite image of XXX Manufacturing Malaysia Sdn. Bhd. (Google Maps, 2023)

3.3 Study Population

3.3.1 Study Duration

The study was carried out across five days from October 23rd 2023 until November 30th 2023.

3.3.2 Subject Criteria

3.3.2.1 Inclusion criteria

Below are the inclusive criteria that were taken into account before choosing the workers as participants in this study:

1. Malaysian.
2. Those who already work in the manufacturing company for more than 6 months.
3. Workers who age between 18-60 years old.

Those who meet the specified inclusion criteria as listed above were identified and contacted for answering the questionnaire and underwent a simple health check-up to measure their blood pressure levels and heart rate.

3.3.2.1 Exclusion criteria

Those who have any criteria as listed below were excluded from this study:

1. Have any history of hearing loss or deformity and have hearing impairment.
2. Medically diagnosed cardiovascular diseases.
3. Had been exposed to loud noise in their previous work (This is to ensure that the loud noise exposure from their previous work does not serve as confounding factors for this study).
4. Had been changing working schedules (shift working to daytime-working or vice versa). Workers who have been changing working shifts are excluded because it can substantially affect sleep patterns, circadian rhythms as well as overall wellbeing.
5. Those with chronic diseases such as asthma, cancer, diabetes, hypertension, and hypercholesterolemia.
6. A smoker.
7. Over 60 years old.

The reason for these factors to be excluded from this study was mainly to avoid or minimize the impact of these confounding factors on the study results and in ensuring a more homogeneous group of subjects as well as more significant results obtained.

3.3.3 Sampling Frame

The sampling frame of this research study was a total of 66 workers. Those 66 workers consist of those who work at Painting line Block B Assembly during the day-shift.

3.4 Sample Size Estimation

In order to obtain a significant result from the data collection, a sample size calculation was used to ensure a sample size that is representative and reliable, to reduce random error from occurring, and to ensure the data obtained is valid to make inferences. The calculations are as below:

$$n = \frac{N(Z_{\alpha/2})^2}{(Z_{\alpha/2})^2 + 4Ne^2} \quad \text{Eq. 3.1.}$$

Where;

N = 66

e = 5%

Thus;

$$n = \frac{66(1.96)^2}{1.96^2 + 4(66)(0.05)^2}$$

The obtained sample size from the calculation above was then adjusted according to the finite population correction formula below (Lavrakas., 2013)

$$N = \frac{n}{1 + (n-1)/100} \quad \text{Eq. 3.2.}$$

n = computed sample size

N = sample size

Therefore;

$$N = \frac{56}{1 + (56 - 1)/100}$$

= 36.1 ~ 36 respondents

The calculated sample size then increased by 5% to take into accounts those respondents who does not complete the questionnaire, error as well as missing data

= 36 + 2 (5%)

= 38 participants

3.5 Sampling Methods

For the selection of workers as participants in this study, purposive sampling was used after taking into account all of the confounders, inclusion, and exclusion criteria.

3.6 Research Tools/ Instruments

3.6.1 Questionnaire

In order to obtain information on demographics, work characteristics, noise exposure, indoor air quality, and cardiovascular health status, participants were given a bilingual (English and Bahasa Malaysia) self-administrated questionnaire. The rationale behind using questionnaires as part of the assessment is solely for the purpose of providing a more extensive understanding of the worker's overall cardiovascular health status. The questionnaire used in this study was a modified questionnaire retrieved from the ICOP For Management of Occupational Noise Exposure and Hearing Conservation (2019), ICOP on Indoor Air Quality (IAQ) (2010), health assessment of noise exposure questionnaire retrieved from the University of California, Berkeley, Guha & Gokhale (2023) study, a Malaysia HEalth and WellBeing Assessment (MyHEBAT) Study Protocol from Firus Khan et al. (2022). The full modified questionnaire document is available in **Appendix C**. The questionnaire comprises of four parts:

1. Part A - socio-demographic and work characteristics

   This part specifically focussed on socio - demographic characteristics and work characteristics of the worker. Socio-demographic information required in this study are gender, age, smoking status, and nationality. On the other hand, work characteristics encompass department /division, job title , work unit, period of employment in the company, and number of hours spent at the main work station. By employing this part (Part A) in this questionnaire, it assisted us in having a more extensive understanding of how these elements might affect the study outcomes.

2. Part B - indoor air quality assessment

   This part was primarily emphasizing the sick building syndrome experienced by the worker for the past three months while working in the automotive manufacturing industry, including the details of the period when they experienced these symptoms. By incorporating this part in this questionnaire, it aided in the identification of potential sources of indoor air quality (IAQ) pollutants and the identification of adverse health effects that may be linked with such exposure to these pollutants.

3. Part C - noise exposure

Under this part of the questionnaire, it assisted in evaluating the worker's exposure to noise in their work environment, specifically regarding hobbies with noise exposure, the use of personal hearing protectors, as well as some questions related to noise induced hearing loss and its determinants in workers.

4. Part D - cardiovascular health status

This part was where the cardiovascular health status of the workers was assessed to estimate the prevalence of their cardiovascular health status due to co-exposure of $PM_{2.5}$ and noise. This Part also served as a complementary to the physiological measurement.

3.6.2 Sound Level Meter Type 1

Figure 3.2: Sound Level Meter Type 1 (SOLO, 01dB, USA)

Sound level meter is an instrument "consisting of a microphone, amplifier and indicating device, having a declared performance, and designed to measure a frequency-weighted and time-weighted value of the sound pressure level" (ICOP, 2019)

Before

1. A microphone was inserted into the SLM body
2. The meter was turned ON by pressing the 'ON/OFF' button.
3. The SLM was calibrated by inserting the calibrator to the microphone subsequently by pressing the 'CAL' button.(The dB level was adjusted to ensure it matched with the sound calibrator output which is 114 dBA).
4. 'OK' button was pressed after the calibration process was completed.
5. A windscreen was then attached to the microphone.

6. The battery level was checked to ensure it is sufficient for the 8-hour monitoring.

During:

1. SLM was pointed to the noise source (1.2 m - 1.5 m above the ground). The reading was then recorded following the stabilization of noise level shown on the screen.
2. A distance of 1 meter away from the noise source was increased.
3. Step 2 was repeated for all directions from the noise source and the average reading for each point was taken after the measurement at the point was repeated for three times.
4. The contour was drawn for noise mapping.

3.6.3 DustTrak

DustTrak is an instrument where it was particularly designed to monitor and measure the airborne particulate matter concentration, which is mainly used in indoor air quality assessments, industrial settings, and occupational hygiene due to its ability to conduct a real-time monitoring.

Figure 3.3: DustTrak II Handheld Aerosol Monitor (TSI, AM520, USA)

3.6.4 Automatic digital Sphygmomanometer

Sphygmomanometer is a medical equipment that indirectly measures arterial blood pressure. It specifically measures systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse in which the optimal range of any person should have a SBP, DBP, and pulse within the range of 120-129 mmHg, 80-84 mmHg, and 60-100 bpm respectively. SBP measures the pressure exerted on the artery walls during every heartbeat, while DBP measures the pressure inside of the arteries when the heart rests between the beats. For this study, the blood pressure of the selected workers will be measured before and after work.

Figure 3.4: Automatic Digital Sphygmamometer (Omron, HEM-7111, Vietnam)

Pickering & Stevens (n.d.) mentioned in their article that there are a few crucial factors that must be considered while measuring the worker's blood pressure, as they can affect the readings and potentially yield false readings. These factors incorporate circumstances where the blood pressure cuff is undersized or is positioned over clothing, whether the worker smoked or consumed any alcohol or caffeine within the previous 30 minutes, whether the worker under a stressed or anxious about having their blood pressure reading taken, or even having a simple conversation during the process of taking the blood pressure. Hence, the study will ensure that the blood pressure measurement will be taken in a meticulous manner and employ all precautions necessary to ensure accurate readings by carefully adhering to the modified method obtained from Center for Disease and Control (CDC), (2023). These methods are:

1. The workers were ensured to sit comfortably with a good back support with a desk/table near them.
2. The workers were allowed to sit quietly for 3-5 minutes.
3. The worker were asked to loosen any tight clothing or remove long-sleeved garments. Arms that have any medical issues were not used.
4. The worker's arm were positioned on a surface that has equal level as their arm and ensure the worker's feet are placed flat on the floor.
5. The inflatable cuff was wrapped around the upper arm (1 inch above the elbow) and secured in place.

6. The cuff tubing was ensured to be on the front center of the worker's arm and connected to the sphygmomanometer tubing.
7. The ON/OFF button was pressed. Then the cuff inflated gradually.
8. The automatic device then deflated.
9. The readings of Systolic pressure (mmHg), diastolic pressure (mmHg), and pulse/min then displayed on the monitor.
10. The readings were repeated for three times and the obtained readings were recorded.
11. Steps 1 to 10 were repeated for after the worker ended their shift.

Among the steps taken to prevent bias in measurement were the workers are ensured to sit in a comfortable way with their back supported and with both of their feet flat on floor, the measurements were also taken multiple times (3x) for each workers to ensure the blood pressure readings are accurate and reliable, lastly, proper cuff size was used in this study. Apart from that, the researcher received an extensive training from a medical practitioner on how to accurately conduct blood pressure measurements using the Automatic Digital Sphygmomanometer on the workers in order to enhance the reliability and accuracy of the results obtained.

3.7 Research Flowchart

This study was conducted after approval from the Ethics Committee for Research Involving Human Subjects (JKEUPM) was obtained. Apart from that, approval from both the Human Resource (HR) department and the Safety and Health Officer (SHO) was also acquired prior to conducting this study at XXX Automotive Manufacturing Industry. After that, all of the workers who participated in this study received a brief overview of this study, and an informed consent form was distributed to the workers for their consent to participate in this study. The data collection then started by calibrating and preparing the equipment used to measure $PM_{2.5}$ and noise levels. Next, the workers answered the questionnaire, and then their blood pressure was measured before and after work. The equipment (DustTrak and SLM) was placed at the polishing work unit as close as possible to both $PM_{2.5}$ and noise exposure. All of the data obtained from the instruments was then analysed using SPSS version 29, and discussions were made based on the findings obtained.

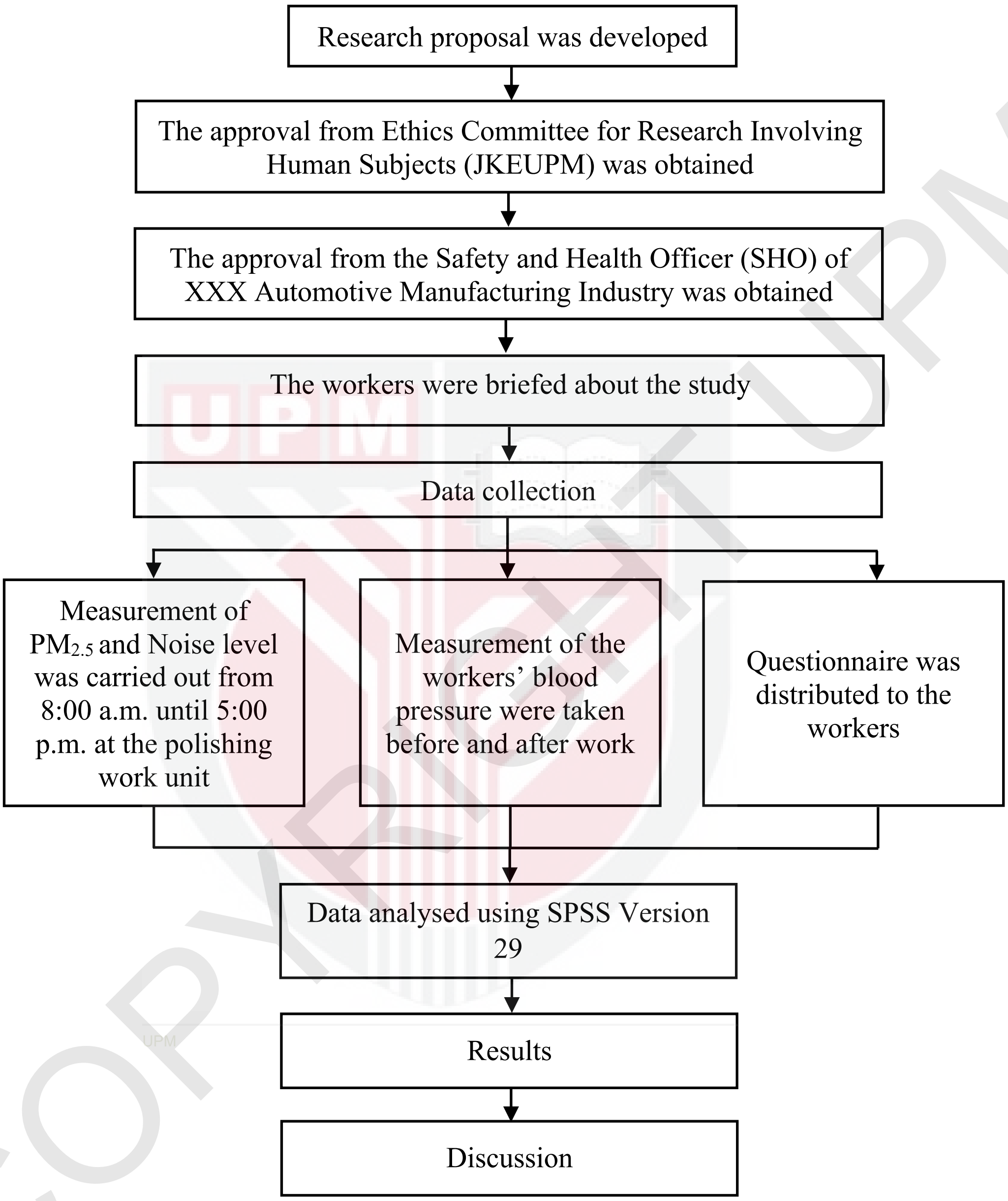


Figure 3.5: Research Flowchart

3.8 Data Analysis

Table 3.1: Statistical analysis used for every specific objectives and types of variables

Specific objectives	Types of variables	Statistical analysis
To determine the socio-demographics and work characteristics of the automotive workers .	1) Socio-demographic - Categorical 2) Work characteristics - Categorical	**Descriptive** - Frequency
To determine and compare particulate matter ($PM_{2.5}$) and noise levels in a selected automotive manufacturing industry in Selangor, Malaysia, with the standard.	1) Level of $PM_{2.5}$ (independent variable) = Quantitative, continuous, numerical (µg/m^3) 2) Level of noise (independent variable) = Quantitative, continuous, numerical (dBA)	**Descriptive** - Graph **Inferential** - T-test
To determine the association between $PM_{2.5}$ and noise exposure	1) Level of $PM_{2.5}$ (independent variable) = Quantitative, continuous, numerical (µg/m^3) 2) Level of noise (independent variable) = Quantitative, continuous, numerical (dBA)	**Inferential** - Spearman correlation
To assess the cardiovascular health status among selected workers in selected automotive manufacturing industry in Selangor, Malaysia	Cardiovascular health status (dependent variable) = Categorical , nominal	**Inferential** - Frequency, percentage
To determine the association of cardiovascular health status among selected workers	1) Level of $PM_{2.5}$ (independent variable) = Quantitative, continuous, numerical	**Inferential** - Non-parametric - spearman rho correlation - Multilinear regression

with the co-exposure of $PM_{2.5}$ and noise.	2) Level of noise (independent variable) Quantitative, continuous, numerical (dBA) 3) Cardiovascular health status (dependent variable) = Categorical , nominal	

3.9 Study Ethics

Approval from the Ethics Committee for Research Involving Human Subjects (JKEUPM) was obtained prior to conducting the research study at XXX Automotive Manufacturing Industry (JKEUPM Ref No.: JKEUPM-2023-703) (refer to Appendix A). With regards to the workers' participation in this study, a brief introduction of the study was given to those workers who were involved in this study for them to grasp the general idea of the study's objectives as well as their involvement in this study. Their permission was also acquired through an informed consent form, where those who only agreed to participate in this study proceeded to participate in this study. Permission from the Human Resources department and the manager of the Safety and Health Department was also granted for the purpose of conducting this study at their company.

CHAPTER 4

RESULTS

4.1 To determine the socio-demographics and work characteristics of the automotive workers .

4.1.1 Response Rate

In total, 37 sets of questionnaire booklets were distributed to the automotive manufacturing workers of XXX Automotive Manufacturing Malaysia Sdn. Bhd. at 'Painting Line Block B Assembly' department. All of the questionnaires were successfully answered and handed back by the respondents, which depicted a response rate of 100%. However, two of the respondents were excluded from this study since they have existing diseases, which are hypertension and diabetes. The calculations for the obtained response rate are as follows:

$$\boldsymbol{Response\ Rate} = \frac{\boldsymbol{Number\ of\ people\ who\ participated\ in\ the\ study}}{\boldsymbol{Total\ number\ of\ recipients\ you\ sent\ it\ to}}\ \boldsymbol{X\ 100} \qquad \text{Eq. 4.1.}$$

$$= \frac{37}{37}\ X\ 100$$

$$= 100\%$$

4.1.2 Sociodemographic Characteristic of Respondents

Among the questions about sociodemographic characteristics are those pertaining to age, gender, pregnancy status, nationality, smoking status, weight, and height. A normality test was conducted for the age variable, and since it is not normally distributed, the median and interquartile range were reported for the age variable (refer to Appendix G.1). As can be seen from Table 4.1. below, the median age of the workers who worked there is 24.0 (±4.0), with the youngest worker being 19 years old and the oldest worker is at the age of 42 years old, where 74.3% of the workers were within the ages of 20 to 29 years old, which accounts for the majority of the workers who worked there. This was followed by the 30 to 39 age group (11.4%), the 10 to 19 age group (8.6%), and lastly, the 40 to 49 age group (5.7%). Of those who participated in this study, 68.6% are male and the other 31.4% are female workers. Among the female respondents who took part in this study, one of them was currently pregnant. Majority (91.4%) of the respondents were Malaysian, while the remaining 8.6% were foreign workers. In terms of smoking status, both smokers and non-smokers shared the same percentage, which is 45.7%, and the remaining 8.6% were ex-smokers. Pertaining to body mass index (BMI), 57.1% of the respondents were categorized as having a normal weight class with a BMI of 18.5 to 25 kg/m^2, 25.7% of them were classified as overweight with a BMI of 25 to 30 kg/m^2, and 8.6% of the respondents were categorized as underweight and obese respectively.

Table 4.1: The summarised results of the respondents' socio-demographics

Sociodemographic	n (%)	Median (±IQR)
Age		
10 – 19	3 (8.6%)	
20 – 29	26 (74.3%)	24.0 (±4)
30 – 39	4 (11.4%)	
40 – 49	2 (5.7%)	
Gender		
Male	24 (68.6%)	
Female	11 (31.4)	
Pregnancy status		
Yes	1 (2.9%)	
No	34 (97.1%)	
Nationality		
Malaysian	32 (91.4%)	
Non-Malaysian	3 (8.6%)	
Smoking status		
Yes	16 (45.7%)	
No	16 (45.7%)	
Ex-smokers	3 (8.6%)	
BMI		
Underweight, <18.5 kg/m^2	3 (8.6%)	
Normal weight, 18.5-25 kg/m^2	20 (57.1%)	

Overweight, 25-30 kg/m^2	9 (25.7%)
Obese, ≥ 30 kg/m^2	3 (8.6%)

4.1.3 Work Characteristics of the Respondents

As for the work characteristics, all of the respondents main job title are working as an operator. As for work units, most of the workers (68.6%) worked at the polish work unit, 22.9% worked at the quality control work unit, 5.7% of them worked at the assembly work unit, and only 2.9% of them worked at the assurance control work unit. In terms of period of employment, the responds were varied; thus, it were grouped into two categories (category 1 = 1-5 years; category 2 = 6-10 years). 94.3% of the respondents worked in the manufacturing industry for 1-5 years , while only 5.7% of them worked for 6-10 years. All of the participants in this study work during the day shift, which is from 8:00 a.m. until 7:00 p.m., where the average number of hours they spend at their main workstation were 12 hours (9 hours excluding break hour). As for working days per week, 88.6% of the workers who engaged in this study worked for 6 days per week, while the other 11.4% of the participants worked for the whole week.

Table 4.2: The summarised result for the respondent's work characteristics

Work characteristics	n (%)
Job title	
Operator	35 (100%)
Work unit	
Polish	24 (68.6%)
Quality control	8 (22.9%)
Assurance control	1 (2.9%)
Assembly	2 (5.7%)
Period of employment	
1 – 5 years	33 (94.3%)
6 – 10 years	2 (5.7%)
Shift work	
Yes	35 (100%)
Number of hours spend at the main work station	
11 hours	35 (100%)
Working days per week	
6 days	31 (88.6%)
7 days	4 (11.4%)

4.1.4 Indoor Quality Assessment

There were a total of six questions pertaining to indoor air quality assessment. Based on the results, none of them answered the “yes” and “no” option to the question asking about whether or not their company or department has ever done any assessment pertaining to indoor air quality, while all of the respondents (100%) were uncertain about the company’s status of the IAQ assessment. According to Table 4.3., drowsiness is the most reported symptom with a percentage of 82.9%, followed by fatigue/lethargy (77.1%), headache (51.4%), fatigue/heavy headed (45.7%), irritated and stuffy nose (28.6%), irritation of the eyes (22.9%), and hoarse/dry throat (20.0%). On the contrary, only 11.4% experienced skin rashes/itchiness symptoms. Based on the participants’ responses, majority (80.0%) of them took zero days off from work due to the previously mentioned symptoms in Table 4.3., below and only 21.6% of them took one day off. Most of the respondents (40.0%) usually developed these symptoms in the morning; only 22.9% of them developed them in the afternoon, while the other 37.1% of them did not notice any trend in the symptoms’ development. Among those who responded, they answered that they experienced relief from these symptoms after they left their work station (25.7%) and building (25.7%). Contrarily, a huge percentage of respondents (48.6%) encountered no noticeable trend of relief. As for the last component of the indoor quality assessment part, majority (62.9%) of the workers were not disturbed or annoyed due to poor indoor quality at their workers; in contrast, 37.1% of the respondents were disturbed because of the aforementioned matter.

Table 4.3: The distribution of symptoms due to poor indoor quality for the past three months

Symptoms due to poor indoor quality	n (%)
Fatigue, heavy headed	
Yes	16 (45.7%)
No	19 (54.3%)
Fatigue / lethargy	
Yes	27 (77.1%)
No	8 (22.9%)
Drowsiness	
Yes	29 (82.9%)
No	6 (17.1%)
Irritation of the eyes	
Yes	8 (22.9%)
No	27 (77.1%)
Skin rashes/itchiness	
Yes	4 (11.4%)
No	31 (88.6%)
Irritated, stuffy nose	
Yes	10 (28.6%)
No	25 (71.4%)
Hoarse/ dry throat	
Yes	7 (20.0%)

No	28 (80.0%)
Headache	
Yes	18 (51.4%)
No	17 (48.6%)

4.1.5 Noise exposure

In the third part of the questionnaire, six questions were asked to assess the noise exposure of the workers. Noise level does not prevent conversation with co-workers at a normal voice level when at work, according to 54.1% of the respondents; however, 45.9% of them do feel that noise level prevents their conversation with other colleagues. 62.2% of the workers do not have any difficulty in following a conversation where two or more workers are speaking at the same time. In contrast, 37.8% answered yes to the question. 78.4%. of the participants does not noticed any ringing or temporary reduction in their hearing after work while the other 21.6% of them noticed the formerly mentioned symptoms. As for the engagement in noisy hobbies, most of the respondents (51.4%) do involved in noisy hobbies while the other 48.6% do not engage with any noisy hobbies. 62.2% of the respondents who worked at the department wear hearing protection mainly ear plug while the remaining 29.7% of the workers do not wear hearing protection where mostly worked at quality control, assurance quality, and assembly work unit. Lastly, most of the workers (70.3%) does not feel disturbed or annoyed due to noise at the workplace. On the contrary, among the respondents, 29.7% of them do feel annoyed or disturbed, and most of them are those who do not work as polishers.

Table 4.4: The summarised noise exposure assessment

Noise exposure assessment	n (%)
Do noise level prevent conversation with co-workers in a normal voice level when at work?	
Yes	16 (45.7%)
No	19 (54.3%)
Do you have trouble following conversation 2/> people talking at the same time?	
Yes	14 (40.0%)
No	21 (60.0%)
Have you noticed ringing or a temporary reduction in hearing after work?	
Yes	8 (22.9%)
No	27 (77.1%)
Do you regularly engaged in a noisy hobbies	
Yes	18 (51.4%)
No	17 (48.6%)
Do you currently use hearing protection?	
Yes	21 (60.0%)
No	14 (40.0%)
Are you disturbed or annoyed due to noise at the workplace?	

Yes	10 (28.6%)
No	25 (71.4%)

4.2 To determine and compare particulate matter ($PM_{2.5}$) and noise levels in a selected automotive manufacturing industry in Selangor, Malaysia, with the standard.

Since the data is not normally distributed ($p<0.05$) (refer to Appendix G.2), a sign test was used to compare $PM_{2.5}$ and noise level with their standards. In accordance with Table 4.5., all of the significance values were less than 0.05, indicating that there is a significant difference in terms of median for both $PM_{2.5}$ and noise levels with their respective recommendation limits.

Table 4.5: Sign test for both $PM_{2.5}$ and noise with their respective recommended value

Variable	Test value	Sig. (2-tailed)
$PM_{2.5}$ level	15	<.001
	35	<.001
Noise level	85	.004

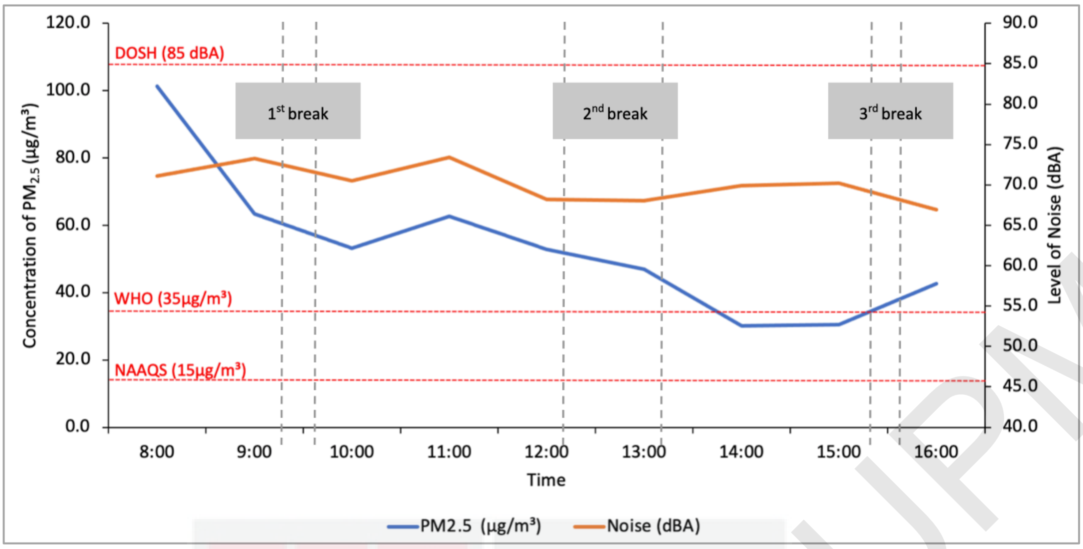


Figure 4.1: The average concentration of $PM_{2.5}$ and noise level for five sampling days, where there was an increase in $PM_{2.5}$ level along with an increment in noise level, and vice versa when the noise level decreased.

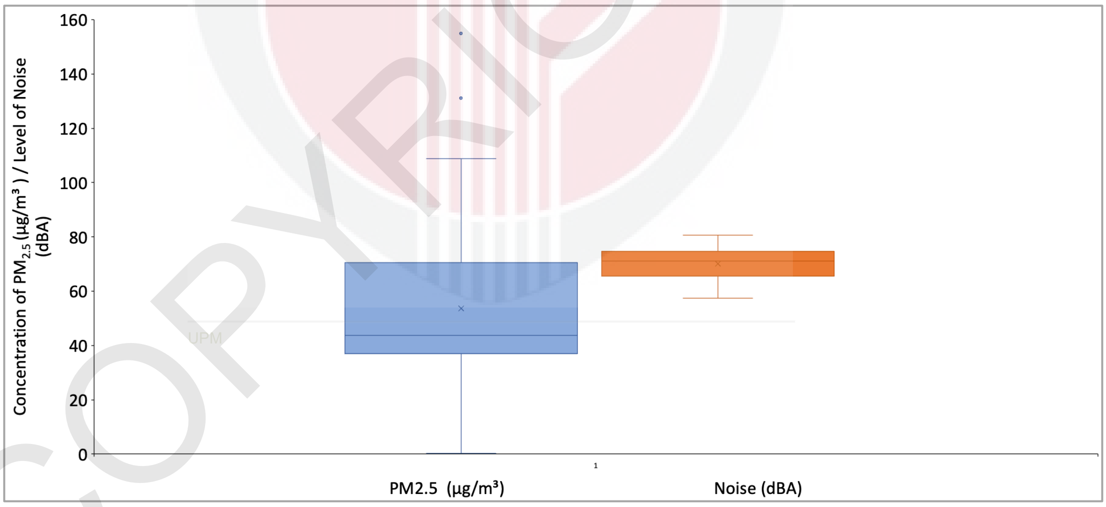


Figure 4.2: Median, quartiles, minimum, maximum, and outlier values for $PM_{2.5}$ and noise.

Figure 4.1. shows the overall $PM_{2.5}$ concentration and noise level for five sampling days. It was noticed that most of the readings of $PM_{2.5}$ levels throughout five sampling were above the recommended standard provided by both the NAAQS (15 µg/m^3) and the WHO (35 µg/m^3), except approximately from 2:00 p.m. until 3:00 p.m., where the readings were within the WHO limit; however, they still exceeded the NAAQS standard, where this particular trend could be seen mostly in the evening part of the day. It was also evident that the trend of $PM_{2.5}$ values peaked in the morning across each of the sampling days, where these were contributed by the polishing work process, which involved the use of chemicals. Throughout the five sampling days, the minimum and maximum levels recorded were 0.2 µg/m^3 and 154.9 µg/m^3 respectively, as depicted in Figure 4.2. As for the noise level which could be seen in Figure 4.1. (orange line), it was observed that the Laeq value did not exceed the limit of 85 dB(A) specified by DOSH for all sampling days. Based on the figure, the type of noise produced by the polishing equipment was categorised as fluctuating noise. Though the noise fluctuated across the sampling day, it was noticeable that the overall noise measurements were high during the morning. The minimum and maximum values of the noise were recorded as 57.9 dB(A) and 80.7 dB(A) respectively.

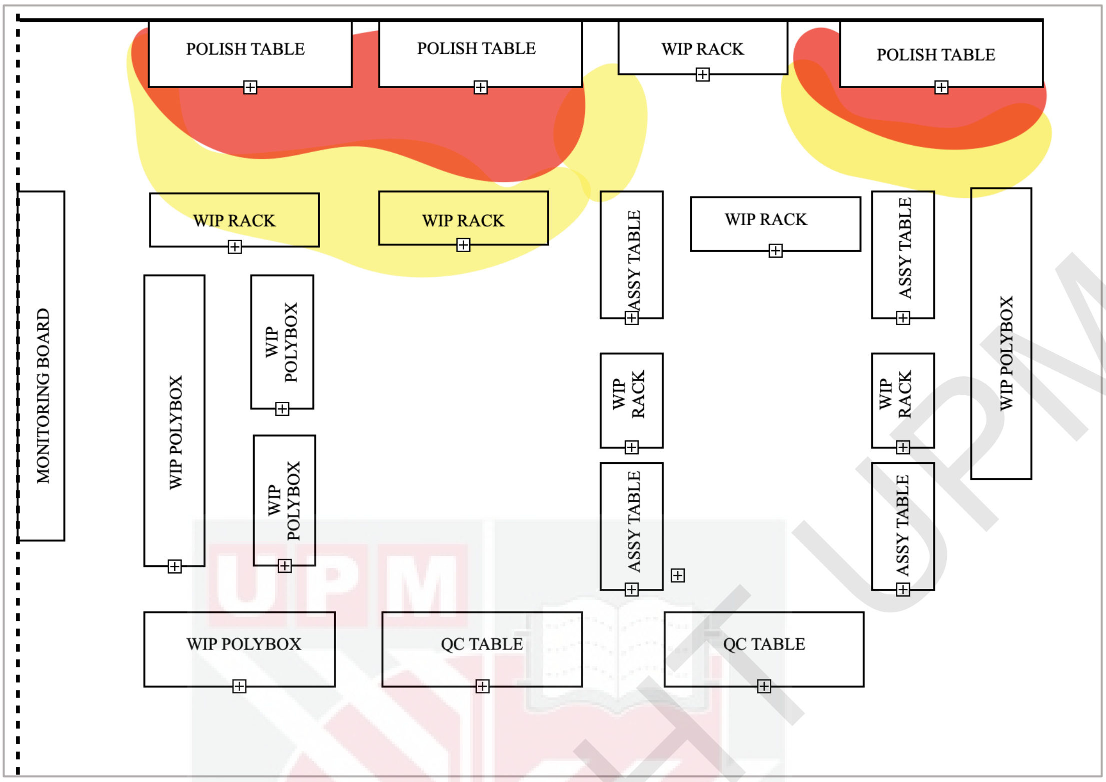


Figure 4.3: The result of noise mapping at polishing work unit (red area = >85dbA to 115 dBA; yellow area = >82 dBA to 85 dBA; white area ≤ 82 dBA)

As for the result of noise mapping from Figure 4.3., it shows that only those workers who were involved in polishing work activity were exposed to noise level > 85 dB(A) (red area), which was caused by the polishing equipment used by the worker. It was also identified that the workers who worked beyond the yellow area, were exposed to noise levels ≤ 82 dB(A).

4.3 The association between particulate matter ($PM_{2.5}$) and noise level exposure

Correlation test was used to measure the relationship between two variables, where in this case are between the concentration of $PM_{2.5}$ and level of noise exposure among workers at the Painting Line Block B Assembly' department. Before that, the assumption of linearity was tested, and it was found to be fulfilled because the relationship between concentration of $PM_{2.5}$ and level of noise exposure of workers is linear. Next, according to the result in Table 4.5. below, the spearman's rho correlation is 0.40, which indicates a positive and moderate correlation between the concentration of $PM_{2.5}$ and level of noise exposure among workers at the Painting Line Block B Assembly department. This suggests that the relationship between the concentration of $PM_{2.5}$ and level of noise measured in this study exists but not strong enough to conclude that one variable increases as the other variable increase.

Table 4.6: Spearman rank correlation analysis for concentration of $PM_{2.5}$ with level of noise

Variables	Concentration of $PM_{2.5}$ (µg/m³)	
	p-value	r
Level of noise (dBA)	0.018	0.40

4.4 To assess the cardiovascular health status among selected workers in selected automotive manufacturing industry in Selangor, Malaysia

Among those who responded, 74.3% of them did not have any family history of cardiovascular-related disease, while the remaining 25.7% of the respondents had a family history of cardiovascular-related disease, particularly diabetes and hypertension. All of those who participated in this study did not take any medication that affected their blood pressure. The majority of the respondents (65.7%) get an average of 7-8 hours of sleep per night; 28.6% of them get an average of 5-6 hours; and only 5.7% of the respondents get more than 8 hours of sleep. Next, regarding the respondents' engagement in night shift work for the day before, all of the respondents did not perform any night shift work yesterday. Apart from that, it is crucial to take note that none of the respondents in our study were diagnosed with diabetes, hypertension, or hypercholesterolemia. Other than that, in the context of the symptoms of cardiovascular diseases that they developed within the past year, majority of the respondents (62.9%) have not experienced any of the symptoms. This was followed by 22.9%, where they experienced at least one of the symptoms listed in the questionnaire; 5.7%, which accounts for those who experienced two symptoms; and 2.9% for each of those who experienced three, five, and six symptoms, respectively. Lastly, concerning the respondents' physical activity engagement for every week, 37.1% of those who answered the questionnaire do not engage in any physical activity, which accounts for the majority. This was followed by 34.3% for 'minimum 30 min/day, 5 days/week of moderate intensity physical activity', and 28.6% for '15 min/day, 5 days/week of vigorous intensity physical activity.

Table 4.7: The questions that are used to assess cardiovascular health status and their results

Questions	n (%)
Do you have any family history of cardiovascular-related diseases?	
Yes	9 (25.7%)
No	26 (74.3%)
Have you taken any medication?	
Yes	3 (8.6%)
No	32 (91.4%)
How many hours of sleep do you have on average per night?	
5-6 hours	10 (28.6%)
7-8 hours	23 (65.7%)
> 8 hours	2 (5.7%)
Did you perform night shift work yesterday?	
No	35 (100%)
Have you ever been diagnosed with any of the diseases below?	
Diabetes	
No	35 (100%)
Hypertension	
No	35 (100%)

Hypercholesterolemia	
No	37 (100%)
Have you ever experienced any of the following in the past year?	
Chest pain or discomfort	
Yes	6 (17.1%)
No	29 (82.9%)
Shortness of breath	
Yes	4 (11.4%)
No	31 (88.6%)
Irregular heartbeat	
Yes	2 (5.7%)
No	33 (94.3%)
Nausea	
Yes	3 (8.6%)
No	32 (91.4%)
Vomiting	
Yes	1 (2.9%)
No	34 (97.1%)
Pain, weakness or numbness in the or arms if the blood vessels in those area are narrowed	
Yes	10 (28.6%)
No	25 (71.4%)
How often do you engage in physical activity each week	

Minimum 30 min/day, 5 days/week of moderate intensity physical activity	12 (34.3%)
15 min/day, 5 days/week of vigorous intensity physical activity.	10 (28.6%)
I do not engage in any physical activity	13 (37.1%)

Table 4.8. Mean ± Standard deviation, Minimum, and maximum levels for blood pressure of the participants before and after work.

Outcome Measures	Mean ± STD	Min - Max
Systolic Blood Pressure (mmHg)		
Before work	121.5 ± 10.7	104.3 – 145.3
After work	116.7 ± 13.2	94.3 – 146.7
Diastolic Blood Pressure (mmHg)		
Before work	70.8 ± 9.8	49.0 – 91.7
After work	65.3 ± 10.2	45.7 – 90.7
Pulse (Bpm)		
Before work	76.9 ± 10.8	60.0 – 105.3
After work	80.0 ± 12.5	51.7 – 117.0

4.5 To determine the association of cardiovascular health status among selected workers with the co-exposure of $PM_{2.5}$ and noise.

Spearman correlation test was carried out first for the independent exposure of $PM_{2.5}$ and noise on cardiovascular health status (blood pressure) in order to have a solid understanding of the effects of individual exposure to cardiovascular health. It was found that the individual exposure to $PM_{2.5}$ and noise did not have a significant relationship with the cardiovascular health status (SBP, DBP, and pulse) of the workers since all of the p values reported were above 0.05.

Table 4.9. Spearman rank correlation analysis of individual exposure of $PM_{2.5}$ and Noise level with blood pressure both before and after work

Variables	Concentration of $PM_{2.5}$ (μg/m³)		Level of Noise (dBA)	
	p-value	r	p-value	r
SBP				
Before	0.087	0.294	0.296	-0.182
After	0.160	0.243	0.967	-0.007
DBP				
Before	0.822	0.039	0.607	-0.090
After	0.837	-0.036	0.784	-0.048
Pulse				
Before	0.512	-0.115	0.502	-0.117
After	0.417	-0.142	0.994	0.001

Table 4.10. The correlation of combined exposure of $PM_{2.5}$ and noise on the cardiovascular health status (blood pressure) using multi linear regression analysis.

Independent variable	Dependent variable	B	SE	p	95% CI
	SBP After	0.168	0.082	**0.049**	**0.001 – 0.335**

$PM_{2.5}$ levels	DBP After	0.048	0.067	0.483	-0.089 – 0.184
	Pulse After	-0.017	0.082	0.842	-0.185 – 0.151
	SBP After	-0.193	0.391	0.625	-0.989 – 0.603
Noise levels	DBP After	-0.156	0.319	0.629	-0.805 – 0.494
	Pulse After	0.036	0.392	0.928	-0.763 – 0.834

CHAPTER 5

DISCUSSIONS

This chapter specifically reviews and discusses the combined exposure of $PM_{2.5}$ and noise on the cardiovascular health status of workers that work at the Painting Line Block B Assembly. All of the data collected were analysed using statistical analysis (SPSS version 29.0).

5.1 Sociodemographic and work characteristics

Some of the obtained data from the questionnaire pertaining to the worker's sociodemographic and work characteristics were not normally distributed ($p < 0.05$); thus, the median and interquartile range (IQR) were reported for this subsection. Our study discovered the disproportion of gender, where the majority of the respondents were male. Statistical analysis (dependent t-test) demonstrates a significant difference between gender and SBP ($p < 0.05$), where this indirectly denotes that gender might be one of the contributing factors that cause an increase or decrease in the worker's systolic blood pressure (refer to Appendix H.1). Similarly, a previous study of cardiovascular health due to exposure to $PM_{2.5}$ originating from traffic and noise pollution of urban workers in different microenvironments indicated that 89.1% of the participants of the study were male (Guha & Gokhale, 2023). Regarding the workers' age, most of them were within the 20-29 age group, and 57.7% of them had a normal BMI, which corresponds with a study carried out by Biel et al. (2020). Next, in terms of the difference between the workers' blood pressure and BMI, it was found that there was a significant difference between them, specifically between the underweight and overweight categories for both SBP and DBP values ($p < 0.05$) (refer to Appendix I.1). Next, the differences in age between the workers also affect their blood pressure, specifically their SBP. Based on Appendix 1.2, it was found that there is a significant difference ($p<0.05$) in relation to SBP (after work measurements) between the age groups of 20-29 and 30-39. In terms of smoking status, it showed that there was a statistical difference in the results between the different smoking status of workers and their SBP after work after ANOVA test was carried out ($P <0.05$) (refer to Appendix I.3). After further post hoc test was done, it was found that the significance difference of SBP was between those who smoke and those who does not smoke, where it was proven from from many studies that smoking could influence the increase of SBP (Wang et al., 2020; Zhang et al., 2021). Regarding the work characteristics of the workers, such as the period of employment, the number of days worked, and their differences in work units, all of them did not affect their blood pressure readings or their pulse (not statistically significant).

5.2 Comparison of $PM_{2.5}$ and noise with the standard

It was noted that throughout the 5 days of measurement, the $PM_{2.5}$ values exceeded both limits set out by NAAQS and WHO. This result correlates with a few studies (Kwarteng et al., 2022; Mohd, J. N. 2012) that were conducted in the same setting as this study. These findings demonstrate strong evidence that automotive workers were mostly exposed to high concentration levels of $PM_{2.5}$, posing them at risk of respiratory and cardiovascular health problems in the long term if suitable personal protective equipment (for instance, N-95 masks) is not used. As for noise, the levels were within the standard; however, there are many studies that exceeded 85 dB(A) (Chen et al., 2019; Xue et al., 2018) where this was because their studies took place at stamping, welding, and forging, in which the nature of these work processes emits loud noise exceeding 85 dB(A). In terms of the noise exposure from the noise mapping, since those who work at the polishing work unit are within the area of noise level >85 dB(A), it is necessary to wear hearing protection devices such as ear plugs or ear muffs at all times during the polishing activity. This is to prevent them from having unwanted diseases such as hearing loss and tinnitus, and especially to minimise the risk of the workers having increased blood pressure due to noise exposure for a long time. For those who worked in areas beyond the red and yellow areas of the noise mapping; for instance, those who worked at the assembly work unit are safe from the noise produced by the polishing equipment; hence, hearing protection devices are unnecessary for that area. However, they could also wear them as a preventive measure. Apart from that, it was observed that there were many WIP (work in progress) racks and trolleys near the polishing work unit that potentially reduced the noise exposure to those who worked at the assembly work unit.

5.3 Association between $PM_{2.5}$ and noise level

Our study found that Spearman's rho correlation is 0.400. Thus, it shows a positive and moderate correlation between $PM_{2.5}$ and noise level (Akoglu, 2018). This signifies that the level of $PM_{2.5}$ does cause an increase in the noise level at the polishing work unit, and the variables are somewhat related, but not to a strong extent. The moderate correlation between these variables occurs due to their originating from the same working activity (polishing). This is because, before the workers start to polish the bumper, they will apply a finishing material to the bumper and use polishing equipment to smooth the surface. Subsequently, this activity produces noise and causes the chemical to become airborne, which justifies the increase in $PM_{2.5}$ concentration and noise level values in Figure 4.1. This result corresponds with a study carried out by Amirul et al. (2021) ($r = 0.66$). There are also a few studies that found a weak correlation between $PM_{2.5}$ and noise level exposure (Biel et al., 2020; Shu et al., 2014), where the correlation coefficients for both studies are 0.27 and 0.12.

5.4 Cardiovascular health status of the workers

Based on the measurement outcomes of the blood pressure in this study, shown in Table 4.8., it shows that the mean SBP and DBP of the participants appeared to reduce after work from 121.5 mmHg to 116.7 mmHg and from 70.8 mmHg to 65.3 mmHg respectively. It is crucial to acknowledge that the results of this study differ with the results obtained in other studies (Chang et al., 2015; Guha & Gokhale., 2023; Melese et al., 2023; Yaghoubi et al., 2018), where their outcomes show a significant increase in SBP as well as in DBP after the measurements take place. For instance, Chang et al. (2015), who studied the short-term exposure of 66 subjects to fine particulate matter, noise, and nitrogen oxides (NO_x) on their ambulatory blood pressure, discovered that the pollutants significantly increased the participants' SBP and DBP. Their study requires the participants to wear an 'ambulatory blood pressure monitor' for 24 hours at their own residence, where the main source of fine particulate matter, noise, and NO_x were from road traffic. Next, regarding the study conducted by Melese et al. (2023), their subjects were among 300 metal manufacturing workers from various factories that primarily focused on metal welding, cutting, and reshaping. Therefore, the reason behind the discrepancies in the outcome in SBP and DBP values from our study with the aforementioned studies might arise from the difference in sample size (too small); it might also be due to the nature of the work, where the location of this study is not too heavy compared with other studies. Confounders that were unpreventable due to limited time could also affect the readings of the workers' blood pressure. As for the pulse of the workers, it was reported to have a slight increase in mean value from 76.9 bpm to 80.0 bpm. This trend in pulse in this study is reasonable since the type of work itself requires some physical exertion. Furthermore, the association between blood pressure values and the category of physical activity and history of cardiovascular disease was not statistically significant, meaning that these categories do not affect the workers' blood pressure measurements. Since most (37.1%) of the workers involved in this study are not involved in any physical activity, this might increase the risk of them having hypertension (Gamage & Seneviratne, 2021).

5.5 The association between the cardiovascular health status with the co-exposure of $PM_{2.5}$ and noise level

Based on Table 4.9., the findings depict that individual exposure to $PM_{2.5}$ and noise does not affect the cardiovascular health (blood pressure and heart rate) of the workers since all of the p-values above 0.05 indicate no correlation. Even though there is no correlation, multiple linear regression was conducted to assess the combined exposure of $PM_{2.5}$ and noise on the workers' cardiovascular health status, and it was identified that the results show a weak correlation with only 11.6% (R-squared = 0.116) of the workers' systolic blood pressure (after work) was influenced by the combined exposure of $PM_{2.5}$ and noise, implying that both of the independent variables do affect the worker's blood pressure to some degree; however, since p was also above 0.05, therefore, there is no association between the combined exposure of $PM_{2.5}$ and noise towards the workers' cardiovascular health status. Contrarily, there are few studies that found a strong association between the previously stated association but with a different setting which is in a traffic-related area (Guha & Gokhale, 2023; Wang et al., 2022). This indicates that more participants should be included in future studies so that it could strengthen the outcome that blood pressure values are strongly associated with $PM_{2.5}$ and noise.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

6.1 Conclusion

In conclusion, after 5 days of measuring $PM_{2.5}$ and noise level at the polishing work unit, it was revealed that gender influences the workers' systolic blood pressure values (SBP) ($p<0.05$). Next, between the categories of workers' BMI, specifically between the overweight and underweight groups, there is a significant difference between those groups in both SBP and DBP values ($p<0.05$). Apart from that, there is also significant difference between the SBP values of those who smoke and those who do not. The level of $PM_{2.5}$ was found to be above the recommended standard for most of the time, with the highest value of 154.9 $\mu g/m^3$. On the contrary, the noise level was noted to be within the recommended standard (85 dBA), with the highest value of 80.7 dB(A). For noise mapping, it was revealed that only those workers who worked at the polishing work unit are exposed to noise levels >85 dB(A). As for the association between $PM_{2.5}$ and noise, there was a moderate correlation between them ($r = 0.40$). For the cardiovascular health status of the workers, there was a decrease in SBP and DBP values with their respective recommended values after work. Lastly, for the combined effect of $PM_{2.5}$ and noise on the workers' cardiovascular health status, no correlation was found since $p>0.05$. But there are many studies that have found a strong association instead, which indicates that sample size should be increased in future studies. Other than that, future research should take into account study locations that are more highly polluted with $PM_{2.5}$ and noise, as well as increase the number of sampling days so that it could easily bring out stronger evidence between the combined effects of $PM_{2.5}$ and noise on cardiovascular status. Nevertheless, control measures such as wearing masks and hearing protectors should be adhered to by the workers who work at the polishing work unit since they are the nearest being directly exposed to both $PM_{2.5}$ and noise. This is to reduce the risk of $PM_{2.5}$ and noise affecting their cardiovascular health status, especially blood pressure, since prolonged elevated blood pressure could cause hypertension.

6.2 Study limitations

In the world of research, having limitations are completely normal, as every study has its own limitations. Since the hypothesis of this study was not met, this indicates that this study has a few limitations, among which are a small sample size and a limited number of sampling days since there was limited time to collect all of the data if it were a large sample size. This might affect the generalizability of the obtained results, as they do not adequately represent the true population. Apart from that, since this study has a restricted number of sampling days, it might miss the crucial fluctuations in $PM_{2.5}$ and noise levels, which might significantly contribute to the association and significance of the study's results. Moreover, there were some exclusion criteria included in this study, such as 'Non-Malaysian' and 'A smoker', which might reduce the internal validity of this study. This situation occurs since there were a limited number of workers that could participate in this study, and there was also a time constraint in conducting this study.

6.3 Recommendation

It is recommended for future studies to increase the sample size as well as the number of sampling days. It is also recommended to conduct study at locations that are more polluted with $PM_{2.5}$ and noise to gain a better understanding of the combined effects of $PM_{2.5}$ and noise on cardiovascular health status, particularly blood pressure. As for the recommendation to the company, control measures such as wearing masks and hearing protectors should be adhered to by the workers who work at the polishing work unit since they are the closest to being directly exposed to both $PM_{2.5}$ and noise (Langrish et al., 2009; DOSH, 2019). This is to reduce the risk of $PM_{2.5}$ and noise affecting their cardiovascular health status in the long term, since prolonged exposure to these variables could cause hypertension due to prolonged elevate blood pressure. Even though there is no association between the combined impact of $PM_{2.5}$ and noise, it is highly recommended for future studies to venture into this particular study as it is undeniably an interesting topic to studied on and knowledge acquired from this type of study could contribute to interventions that could significantly reduce the workers exposure to $PM_{2.5}$ and noise, subsequently improving their overall health and well-being.

REFERENCES

Ain, N. U., & Qamar, S. U. R. (2021). Particulate Matter-Induced Cardiovascular Dysfunction: A Mechanistic Insight. *Cardiovascular Toxicology*, *21*(7), 505–516. https://doi.org/10.1007/s12012-021-09652-3

Alnabih, A. I. A., Bin Mat Tahir, M. F., & Khamis, N. K. (2021). Evaluation of Occupational Noise Exposure in a Plastic Manufacturing Industry: A Case Study. *Jurnal Kejuruteraan*, *33*(3), 699–707. https://doi.org/10.17576/jkukm-2021-33(3)-28

Alagapan, P., Hassan, M., Ibrahim, M., Daud, M., Bani, N., & Kutty, R. M. (2019). Measurement of hazardous personal noise exposure in spice manufacturing industry. *Journal of Physics: Conference Series*, *1150*, 012021. https://doi.org/10.1088/1742-6596/1150/1/012021

Basith, S., Manavalan, B., Shin, T. H., Park, C. B., Lee, W. S., Kim, J., & Lee, G. (2022). The Impact of Fine Particulate Matter 2.5 on the Cardiovascular System: A Review of the Invisible Killer. *Nanomaterials*, *12*(15), 2656. https://doi.org/10.3390/nano12152656

Biel, R., Danieli, C., Shekarrizfard, M., Minet, L., Abrahamowicz, M., Baumgartner, J., Liu, R., Hatzopoulou, M., & Weichenthal, S. (2020). Acute cardiovascular health effects in a panel study of personal exposure to traffic-related air pollutants and noise in Toronto, Canada. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-73412-6

Buregeya, J. M., Apparicio, P., & Gelb, J. (2020). Short-Term Impact of Traffic-Related Particulate Matter and Noise Exposure on Cardiac Function. *International Journal of Environmental Research and Public Health*, *17*(4), 1220. https://doi.org/10.3390/ijerph17041220

Chang, L. T., Chuang, K. J., Yang, W. T., Wang, V. S., Chuang, H. C., Bao, B. Y., Liu, C. S., & Chang, T. Y. (2015). Short-term exposure to noise, fine particulate matter and nitrogen oxides on ambulatory blood pressure: A repeated-measure study. *Environmental Research*, *140*, 634–640. https://doi.org/10.1016/j.envres.2015.06.004

Chen, X., Liu, M., Zuo, L., Wu, X., Chen, M., Li, X., An, T., Chen, L., Xu, W., Peng, S., Chen, H., Liang, X., & Hao, G. (2023). Environmental noise exposure and health outcomes: an umbrella review of systematic reviews and meta-analysis. *European Journal of Public Health*, *33*(4), 725–731. https://doi.org/10.1093/eurpub/ckad044

Chen, Y., Zhang, M., Qiu, W., Sun, X., Wang, X., Dong, Y., Chen, Z., & Hu, W. (2019). Prevalence and determinants of noise-induced hearing loss among workers in the automotive industry in China: A pilot study. *Journal of Occupational Health*, *61*(5), 387–397. https://doi.org/10.1002/1348-9585.12066

Chuang, K. J., Lin, L. Y., Ho, K. F., & Su, C. T. (2020). Traffic-related PM2.5 exposure and its cardiovascular effects among healthy commuters in Taipei, Taiwan. *Atmospheric Environment: X*, *7*, 100084. https://doi.org/10.1016/j.aeaoa.2020.100084

Civil, C. (2022). *The importance of using automatic blood pressure measuring devices in hypertension patients*. http://jbionicmemory.com/index.php/jbm/article/view/31

Dallos, J. (2019). *Air Quality Issues in Automotive Manufacturing - FABTECH*. FABTECH. https://www.fabtechexpo.com/blog/2019/04/05/air-quality-issues-in-automotive-manufacturing

D'Arcy, J., Dasch, J., Gundrum, A., Rivera, J., Johnson, J., Carlson, D., & Sutherland, J. W. (2016). Characterization of process air emissions in automotive production plants. *Journal of Occupational and Environmental Hygiene*, *13*(1), 9–18. https://doi.org/10.1080/15459624.2015.1076161

Department of Occupational Safety and Health. (2019). Industry Code of Practice For Management of Occupational Noise Exposure and Hearing Conservation. *Department of Occupational Safety and Health*. https://www.dosh.gov.my/index.php/legislation/codes-of-practice/industrial-hygiene/3286-industry-code-of-practice-for-management-of-occupational-noise-exposure-and-hearing-conservation-2019/file

Department of Statistics Malaysia Official Portal. (n.d.). Big data analytics : National occupational accident and disease statistics 2021. *Department of Statistics Malaysia*. https://v1.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=492&bul_id=MkRoQ2IyZ0JkdElIZ0JidUhpaWxydz09&menu_id=WjJGK0Z5bTk1ZElVT09yUW1tRG41Zz09

Du, Y., Xu, X., Chu, M., Guo, Y., & Wang, J. (2016). Air particulate matter and cardiovascular disease: the epidemiological, biomedical and clinical evidence. *PubMed*. https://doi.org/10.3978/j.issn.2072-1439.2015.11.37

Favero, T. G., Zable, A. C., & Abramson, J. J. (1995). Hydrogen Peroxide Stimulates the Ca2+ Release Channel from Skeletal Muscle Sarcoplasmic Reticulum. *Journal of Biological Chemistry*, *270*(43), 25557–25563. https://doi.org/10.1074/jbc.270.43.25557

Feng, S., Huang, F., Zhang, Y., Feng, Y., Zhang, Y., Cao, Y., & Wang, X. (2023). The pathophysiological and molecular mechanisms of atmospheric PM2.5 affecting cardiovascular health: A review. Ecotoxicology and Environmental Safety, 249, 114444. https://doi.org/10.1016/j.ecoenv.2022.114444

Firsthand. (n.d.). Firsthand. https://firsthand.co/professions/automotive-industry-workers

Firus Khan, A. Y., Ramli, A. S., Abdul Razak, S., Mohd Kasim, N. A., Chua, Y. A., Ul-Saufie, A. Z., Jalaludin, M. A., & Nawawi, H. (2022). The Malaysian HEalth and WellBeing AssessmenT (MyHEBAT) Study Protocol: An Initiation of a National Registry for Extended Cardiovascular Risk Evaluation in the Community. *International Journal of Environmental Research and Public Health*, *19*(18), 11789. https://doi.org/10.3390/ijerph191811789

Guha, A. K., & Gokhale, S. (2023). Urban workers' cardiovascular health due to exposure to traffic-originated PM2.5 and noise pollution in different microenvironments. Science of the Total Environment, 859, 160268. https://doi.org/10.1016/j.scitotenv.2022.160268

Huang, Y., Bao, M., Xiao, J., Qiu, Z., & Wu, K. (2019). Effects of PM2.5 on Cardio-Pulmonary Function Injury in Open Manganese Mine Workers. *International Journal of Environmental Research and Public Health*, *16*(11), 2017. https://doi.org/10.3390/ijerph16112017

Kritsch,B., (2022). Your Cardiovascular Health Goes Way Beyond Your Heart. SELF. https://www.self.com/health-conditions/cardiovascular-health

Li, X., Dong, Q., Wang, B., Song, H., Wang, S., & Zhu, B. (2019). The Influence of Occupational Noise Exposure on Cardiovascular and Hearing Conditions among Industrial Workers. *Scientific Reports*, *9*(1). https://doi.org/10.1038/s41598-019-47901-2

Liang, X., Chen, J., An, X., Liu, F., Liang, F., Tang, X., & Qü, P. (2022). *The impact of PM2.5 on children's blood pressure growth curves: A prospective cohort study*. Environment International; Elsevier BV. https://doi.org/10.1016/j.envint.2021.107012

Liwinska-Kowalska, M., Zamyslowska-Szmytke, E., Szymczak, W., Kotylo, P., Fiszer, M., Wesolowski, W., Pawlaczyk-Luszczynska, M., Bak, M., & Gajda-Szadkowska, A. (2004). Effects of Coexposure to Noise and Mixture of Organic Solvents on Hearing in Dockyard Workers. *Journal of Occupational and Environmental Medicine*, *46*(1), 30–38. https://doi.org/10.1097/01.jom.0000105912.29242.5b

Lopez, E. O., Ballard, B. D., & Jan, A. (2022). Cardiovascular Disease - StatPearls - NCBI Bookshelf. Cardiovascular Disease - StatPearls - NCBI Bookshelf. https://www.ncbi.nlm.nih.gov/books/NBK535419/

Luna-Carrascal, J., Olivero-Verbel, J., Acosta-Hoyos, A. J., & Quintana-Sosa, M. (2023). Auto repair workers exposed to PM2.5 particulate matter in Barranquilla, Colombia: Telomere length and hematological parameters. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, *887*, 503597. https://doi.org/10.1016/j.mrgentox.2023.503597

Melese, M., Adera, A., Ambelu, A., Gela, Y. Y., & Diress, M. (2023). Occupational Noise-Induced Pre-Hypertension and Determinant Factors Among Metal Manufacturing Workers in Gondar City Administration, Northwest Ethiopia. *Vascular Health and Risk Management*, *Volume 19*, 21–30. https://doi.org/10.2147/vhrm.s392876

Münzel, T., Schmidt, F. P., Steven, S., Herzog, J., Daiber, A., & Sørensen, M. (2018). Environmental Noise and the Cardiovascular System. *Journal of the American College of Cardiology*, *71*(6), 688–697. https://doi.org/10.1016/j.jacc.2017.12.015

Mustaffa, N. F., & Megat, M. M. A. (2018). Exposure of Fine Particulate Matter ($PM_{2.5}$) in Automotive Industry Among Fitting Line Workers and Health risk Assessment. https://ir.uitm.edu.my/id/eprint/45679/1/45679.pdf

Nelin, T. D., Joseph, A. M., Gorr, M. W., & Wold, L. E. (2012). Direct and indirect effects of particulate matter on the cardiovascular system. *Toxicology Letters*, *208*(3), 293–299. https://doi.org/10.1016/j.toxlet.2011.11.008

Nguyen, T. H. Y., Bertin, M., Bodin, J., Fouquet, N., Bonvallot, N., & Roquelaure, Y. (2018). Multiple Exposures and Coexposures to Occupational Hazards Among Agricultural Workers: A Systematic Review of Observational Studies. *Safety and Health at Work*, *9*(3), 239–248. https://doi.org/10.1016/j.shaw.2018.04.002

OSHA Technical Manual (OTM) - Section III: Chapter 5 | Occupational Safety and Health Administration. (n.d.). https://www.osha.gov/otm/section-3-health-hazards/chapter-5

Patino, C. M., & Ferreira, J. C. (2018). Inclusion and exclusion criteria in research studies: definitions and why they matter. SciELO - Brazil - Inclusion and Exclusion Criteria in Research Studies: Definitions and Why They Matter. https://doi.org/10.1590/S1806-37562018000000088

Pickering, D., & Stevens, S. (n.d.). *How to measure and record blood pressure*. PubMed Central (PMC). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3936692/

Rabiei, H., Ramezanifar, S., Hassanipour, S., & Gharari, N. (2021). Investigating the effects of occupational and environmental noise on cardiovascular diseases: a systematic review and meta-analysis. *Environmental Science and Pollution Research*, *28*(44), 62012–62029. https://doi.org/10.1007/s11356-021-16540-4

Recio, A., Linares, C., Banegas, J. R., & Díaz, J. (2016, April). Road traffic noise effects on cardiovascular, respiratory, and metabolic health: An integrative model of biological mechanisms. *Environmental Research*, *146*, 359–370. https://doi.org/10.1016/j.envres.2015.12.036

Reid, I. R., Birstow, S. M., & Bolland, M. J. (2017). Calcium and Cardiovascular Disease. *PubMed Central (PMC)*. https://doi.org/10.3803/EnM.2017.32.3.339

Ren, J., Guo, X. L., LU, Z. L., Zhang, J. Y., Tang, J. L., Chen, X., Gao, C. C., Xu, C. X., & Xu, A. Q. (2016). Ideal cardiovascular health status and its association with socioeconomic factors in Chinese adults in Shandong, China. *BMC Public Health*, *16*(1). https://doi.org/10.1186/s12889-016-3632-6

Rizky, Z. P., Yolla, P. B., & Ramdhan, D. H. (2016). Particulate matter 2.5 (PM2.5) personal exposure evaluation on mechanics and administrative officers at the motor vehicle testing center at Pulo Gadung, DKI Jakarta. *Reviews on Environmental Health*, *31*(1), 185–186. https://doi.org/10.1515/reveh-2015-0057

Setia, M. S. (2016). *Methodology series module 3: Cross-sectional studies Setia MS - Indian J Dermatol*. Methodology Series Module 3: Cross-sectional Studies Setia MS - Indian J Dermatol. https://doi.org/10.4103/0019-5154.182410

Themann, C. L., & Masterson, E. A. (2019). Occupational noise exposure: A review of its effects, epidemiology, and impact with recommendations for reducing its burden. *The Journal of the Acoustical Society of America*, *146*(5), 3879–3905. https://doi.org/10.1121/1.5134465

The Star. (2022). DOSH alarmed by rise of occupational hearing loss cases. *The Star*. https://www.thestar.com.my/news/nation/2022/08/11/dosh-alarmed-by-rise-of-occupational-hearing-loss-cases

USEPA. (2023). Particulate Matter (PM) basics. *United States Environmental Protection Agency (USEPA)*. https://www.epa.gov/pm-pollution/particulate-matter-pm basics#:~:text=PM2.5%20%3A%20fine%20inhalable%20particles,than%20the%20largest%20fine%20particle

Vinnikov, D., & Tulekov, Z. (2020). Plasma cutting and exposure to PM2.5 metal aerosol in metalworking, Almaty, Kazakhstan, 2020. *Occupational and Environmental Medicine*, *78*(3), 218–220. https://doi.org/10.1136/oemed-2020-106883

Wang, M., Li, W., Zhou, R., Wang, S., Zheng, H., Jiang, J., Wang, S., Yu, C., Gao, W., Lv, J., Wu, T., Cao, W., Hu, Y., Li, L., & Ji, J. S. (2020). The Paradox Association between Smoking and Blood Pressure among Half Million Chinese People. *International Journal of Environmental Research and Public Health*, *17*(8), 2824. https://doi.org/10.3390/ijerph17082824

Wang, Y., Xiao, S., Zhang, Y., Chang, H., Martin, R. V., Van Donkelaar, A., Gaskins, A., Liu, Y., Liu, P., & Shi, L. (2022, January). Long-term exposure to PM2.5 major components and mortality in the southeastern United States. *Environment International*, *158*, 106969. https://doi.org/10.1016/j.envint.2021.106969

Wang, Z., Liang, J., Rong, X., Zhou, H., Duan, C., Du, W., & Liu, Y. (2015). Noise hazard and hearing loss in workers in automotive component manufacturing industry in Guangzhou, China. *Chinese Journal of Industrial Hygiene and Occupational Diseases*, *33*(12), 906–909. https://doi.org/10.3760/cma.j.issn.1001-9391.2015.12.007

World Health Organization. (2021). Cardiovascular diseases. *World Health Organization (WHO)*. https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

Wojtyto, D., Michalik, J., & Angelova, M. (2021). Noise Level Measurement and Analysis in a Manufacturing Enterprise. *System Safety: Human - Technical Facility - Environment, 3*(1), 192–200. https://doi.org/10.2478/czoto-2021-0020

Xue, C. H., Tao, Z. M., Su, Y. W., Li, E. B., Zhou, M., Bao, M. Y., & Liu, Y. M. (2018). [Analysis on hearing status and related influencing factors in workers exposed to noise in an automobile manufacture enterprise]. *Chinese journal of industrial hygiene and occupational diseases, 36*(3), 204-207. 10.3760/cma.j.issn.1001-9391.2018.03.011

Yang, L., Li, C., & Tang, X. (2020). The Impact of PM2.5 on the Host Defense of Respiratory System. *Frontiers in Cell and Developmental Biology*, *8*. https://doi.org/10.3389/fcell.2020.00091

Zamanian, Z., Rostami, R., Hasanzadeh, J., & Hashemi, H. (2013). Investigation of the Effect of Occupational Noise Exposure on Blood Pressure and Heart Rate of Steel Industry Workers. *Journal of Environmental and Public Health*, *2013*, 1–3. https://doi.org/10.1155/2013/256060

Zhang, Y., Feng, Y., Chen, S., Liang, S., Wang, S., Xu, K., Ning, D., Yuan, X., Zhu, H., Pan, H., & Shan, G. (2021, January 14). Relationship between the duration of smoking and blood pressure in Han and ethnic minority populations: a cross-sectional study in China. *BMC Public Health*, *21*(1). https://doi.org/10.1186/s12889-020-09975-w

Zulkefli NAM, Rusli MFB, Rahman AA. (2017). Predictors of knowledge, attitude and practice of noise induced hearing loss among workers in an automotive industry in Malaysia. *Malaysian Journal of Medicine and Health Sciences*. *13*(1), 61–68.

ETHICS COMMITTEE FOR RESEARCH INVOLVING HUMAN SUBJECTS (JKEUPM)
UNIVERSITI PUTRA MALAYSIA

Research title	:	**The Coexposure of Pm2.5 And Noise Among Casting Workers And Their Cardiovascular Health Status in A Selected Manufacturing Industry In Selangor, Malaysia.**
Study Site	:	**Selangor.**
JKEUPM Ref No.	:	**JKEUPM-2023-703**
Principal Investigator	:	**Dr. Nor Eliani Ezani**
Co-investigator	:	**Aneesah Amani Binti Suffian (Student)**

Documents received and reviewed with reference to the above study:

1. Ethics Application Form, Version 1 dated 14/07/2023.
2. Respondent's Information Sheet / Consent (English), Version 2 dated 12/10/2023.
3. Proposal (English), Version 2 dated 09/10/2023.
4. Questionnaire / Interviews (English), Version 2 dated 09/10/2023.
5. Curriculum Vitae of:
    a. Dr. Nor Eliani Ezani

The University Research Ethics Committee, Universiti Putra Malaysia (JKEUPM) operates in accordance to the ICH-GCP Guidelines.
Decision by JKEUPM:

[x] Approved

[x] **Permission MUST BE OBTAINED from the respective hospitals/ institutions before conducting the research**

[ ] Disapproved

Please note that the approval is **VALID UNTIL 25 OCTOBER 2024**

Researchers should comply with the following:

I. Complete a Study Final Report upon study completion (Form 3.2).

II. Ethical approval is required in the case of amendments/ changes to the study documents/ study sites/ study team.

III. Applicable for Clinical Trial Studies and Clinical interventional Studies only: Progress Report has to be submitted to JKEUPM at every 6 months from the date of approval (Form 3.1). Report occurrences of all Serious Adverse Events (SAEs), Suspected Unexpected Serious Adverse Reaction (SUSARs) and Protocol Deviation/ Violation at all JKEUPM approved sites to JKEUPM. All serious adverse events (SAEs) detected or being notified should be reported immediately to the sponsor except for those SAEs that the protocol or other document (e.g., Investigator's Brochure) identifies as not needing immediate reporting. The immediate reports should be followed promptly by detailed, written reports.

Appendix B: Informed consent form

JAWATANKUASA ETIKA UNIVERSITI UNTUK PENYELIDIKAN MELIBATKAN MANUSIA (JKEUPM)
UNIVERSITI PUTRA MALAYSIA, 43400 UPM SERDANG, SELANGOR, MALAYSIA

BORANG 2.4: PENERANGAN DAN PERSETUJUAN RESPONDEN

Sila baca maklumat berikut dengan teliti. Sekiranya anda mempunyai sebarang pertanyaan, sila kemukakan kepada penyelidik.

1.TAJUK KAJIAN

Pendedahan Bersama Bahan Zarah ($PM_{2.5}$) dan Bunyi Dikalangan Pekerja Automotif dan Status Kesihatan Kardiovaskular Mereka Dalam Industri Pembuatan Kenderaan Terpilih di Selangor, Malaysia.

2. PENGENALAN

Status kesihatan kardiovaskular merujuk kepada kesejahteraan jantung dan saluran darah; kesihatan kardiovaskular yang baik menunjukkan bahawa jantung, saluran darah, dan sistem peredaran darah individu berada dalam keadaan baik dan mampu menjalankan fungsi mereka dengan berkesan. Kesihatan kardiovaskular boleh dipengaruhi oleh pelbagai faktor, salah satunya adalah tekanan darah tinggi, yang boleh disebabkan oleh pendedahan akut kepada bunyi kuat melebihi 85 desibel dan pendedahan kepada bahan zarah halus (PM2.5) tahap tinggi semasa waktu bekerja. Sebagai permulaan, PM2.5 adalah zarah halus dengan diameter 2.5 mikrometer atau kurang sementara bunyi pekerjaan adalah bunyi tidak diingini atau kombinasi bunyi yang memberi kesan buruk kepada kesihatan pekerja. Kesan ini terdiri daripada gangguan dalam pemprosesan kognitif kepada menjejaskan kesihatan mental dan fizikal, bergantung pada ciri, keamatan dan sifat bunyi. Pendedahan gabungan kepada kedua-dua faktor ini boleh memperburuk kesan kepada kesihatan kardiovaskular, terutamanya berkaitan dengan tekanan darah dan kadar jantung.

Oleh itu, kajian ini dijalankan untuk mengaitkan antara pendedahan bersama PM2.5 dan bunyi di kalangan pekerja automotif serta status kesihatan kardiovaskular mereka dalam industri pembuatan automotif terpilih di Selangor, Malaysia.

3. APAKAH YANG PERLU ANDA LAKUKAN?

1- Pertama sekali, anda dikehendaki membaca dan memahami semua maklumat yang dinyatakan dalam Borang 2.4 (lembaran maklumat responden dan borang persetujuan yang diberi maklumat).
2- Selepas itu, jika anda memutuskan untuk mengambil bahagian dalam kajian ini, anda dikehendaki mengisi tanda tangan anda pada halaman terakhir borang ini. (Sila ambil perhatian bahawa mereka yang menyertai kajian ini tidak akan diberikan sebarang honorarium atau insentif).
3- Kemudian, anda dikehendaki untuk mengisi satu set soal selidik yang akan diberikan kepada anda dan mengembalikannya kepada penyelidik setelah anda selesai menjawab semua soalan. Soal selidik ini terbahagi kepada empat bahagian: Bahagian A (Maklumat latar belakang dan ciri-ciri kerja), Bahagian B (Penilaian kualiti udara dalaman), Bahagian C (Penilaian pendedahan bunyi), dan Bahagian D (status kesihatan kardiovaskular) yang dianggarkan akan mengambil masa kira-kira 10-15 minit untuk mengisi soal selidik ini. Perlu diingatkan bahawa anda mempunyai pilihan untuk terus mengambil bahagian dalam kajian ini atau menarik diri pada bila-bila masa semasa mengisi soal selidik.

JKEUPM/FORM 2.4
VERSION: 1 DECEMBER 2022
Page 1

4- Seterusnya, terdapat dua alat yang akan dipasang pada badan anda iaitu dosimeter dan SidePak sebelum anda memulakan shif kerja anda dan akan ditanggalkan pada akhir shift kerja dan semasa sebarang rehat atau lawatan ke tandas. (Pembantu lelaki akan memasang alat kepada pekerja lelaki, manakala pembantu perempuan akan memasang instrumen kepada pekerja Wanita.)
5- Akhir sekali, sebagai satu bentuk penjagaan perubatan asas, anda dikehendaki mengambil ujian tekanan darah sebelum dan selepas bekerja.

4. SIAPA YANG TIDAK BOLEH MENYERTAI KAJIAN INI?
Pekerja yang:
(a) Mempunyai sejarah kehilangan pendengaran atau kecacatan telinga
(b) Berada dalam latihan luar negara atau cuti perubatan
(c) Mempunyai penyakit kardiovaskular yang sedia ada
(d) Telah terdedah kepada bunyi bising dalam pekerjaan sebelum ini
(e) Telah menukar jadual kerja (daripada bekerja bergilir kepada waktu siang atau sebaliknya)
(f) Merokok
(g) Bekerja kurang dari enam bulan di syarikat tersebut
(h) Berumur lebih dari 60 tahun
(i) Mempunyai penyakit kronik (Contohnya: hipertensi, diabetes jenis 2, dan lain-lain)

Kelayakan pekerja untuk menyertai kajian ini akan ditentukan dengan meninjau rekod perubatan mereka. Penilaian menyeluruh ini yang berfungsi sebagai saringan awal digunakan semata-mata untuk tujuan penyelidikan dan bertujuan untuk memastikan pekerja memenuhi kriteria kesihatan yang diperlukan untuk penyertaan dalam kajian, serta untuk memastikan kebolehpercayaan dan kesahihan hasil penyelidikan.

5. APAKAH FAEDAH MENYERTAI KAJIAN INI?

a) KEPADA ANDA SEBAGAI PESERTA?

Bagi mereka yang mengambil bahagian dalam kajian ini, anda akan mendapatkan pengetahuan yang penting mengenai status kesihatan kardiovaskular anda apabila mengisi soal selidik serta menjalani ujian tekanan darah. Dengan melakukan itu, anda dapat mengambil langkah pencegahan yang sesuai untuk mengelakkan komplikasi kesihatan kardiovaskular yang lebih teruk, seperti mendapatkan nasihat doktor atau mengamalkan gaya hidup yang lebih sihat. Selain itu, anda juga dapat mengetahui pendedahan sebenar bunyi dan $PM_{2.5}$ anda, kerana kami akan memberikan anda keputusan selepas mentafsir data yang diperoleh daripada pengukuran yang telah selesai. Oleh itu, anda akan sedar tentang kepentingan penggunaan peralatan perlindungan diri yang sesuai dan betul yang disediakan oleh majikan pada setiap masa semasa bekerja. Dengan mengambil bahagian dalam kajian ini, anda akan memperoleh pengetahuan baru mengenai hubungan antara pendedahan bunyi dan $PM_{2.5}$ dengan status kesihatan kardiovaskular anda. Langkah-langkah yang sesuai akan diberikan kepada anda jika hubungan antara bunyi dan $PM_{2.5}$ dengan status kesihatan kardiovaskular pekerja automotif terbukti daripada kajian ini, bagi mengurangkan risiko anda mendapat status kesihatan kardiovaskular yang buruk.

b) KEPADA PENYELIDIK?

Penyelidikan ini akan memberi manfaat kepada penyelidik dalam pelbagai cara, kerana semua maklumat yang diperoleh daripada kajian ini akan membantu penyelidik menganalisis dan menguatkan hubungan antara pendedahan bersama bunyi dan zarah halus ($PM_{2.5}$) dengan status kesihatan kardiovaskular pekerja pembuatan terpilih. Selain itu, kajian ini akan memberikan wawasan dan pemahaman mendalam tentang bagaimana bunyi dan $PM_{2.5}$ dapat mempengaruhi status kesihatan kardiovaskular seseorang.

6. ADAKAH IA BERISIKO?

Peserta dalam kajian ini tidak akan menghadapi sebarang potensi risiko kerana tiada kaedah pengumpulan data invasif digunakan. Kajian ini secara eksklusif menggunakan soal selidik yang diisi sendiri oleh peserta, dosimeter, sfigmomanometer digital automatik, dan SidePak, yang semuanya tidak bersifat invasif. Perlu diperhatikan bahawa kaedah-kaedah ini memberi keutamaan kepada keselamatan peserta dan tidak melibatkan prosedur invasif apa pun.

7. ADAKAH MAKLUMAT DAN IDENTITI SAYA KEKAL RAHSIA?

Ya, semua maklumat dan identiti pekerja yang mengambil bahagian dalam kajian ini tidak akan didedahkan, akan dirahsiakan dan digunakan semata-mata untuk tujuan penyelidikan. Semua maklumat yang diperoleh mengenai setiap pekerja akan diberi penanda unik sebagai ganti menggunakan nama pekerja tersebut.

8. SIAPA YANG SAYA PERLU HUBUNGI SEKIRANYA SAYA MEMPUNYAI SOALAN TAMBAHAN SEMASA MENGIKUTI PENYELIDIKAN INI?

Penyelidik: **Aneesah Amani Binti Suffian** No. Telefon: **019-3212702** Emel: 207608@student.upm.edu.my	Penyelia penyelidikan: **Dr. Nor Eliani Binti Ezani** No telefon: **019-2894449** Emel: elianiezani@upm.edu.my

Jika anda mempunyai sebarang pertanyaan berkaitan dengan hak-hak anda sebagai peserta dalam penyelidikan ini, sila hubungi: Sekretariat, JKEUPM, melalui email: **jkeupm@upm.edu.my**

Sila tandatangan di sini sekiranya anda telah membaca dan memahami kandungan halaman ini _______

Appendix C: Questionnaire booklet

Universiti Putra Malaysia

Faculty of Medicine and Health Sciences

Department of Environmental and Occupational Health

QUESTIONNAIRE
(BORANG SOAL SELIDIK)

THE COEXPOSURE OF PARTICULATE MATTER (PM2.5) AND NOISE AMONG AUTOMOTIVE WORKERS AND THEIR CARDIOVASCULAR HEALTH STATUS IN A SELECTED AUTOMOTIVE MANUFACTURING INDUSTRY IN SELANGOR, MALAYSIA

PENDEDAHAN BERSAMA BAHAN ZARAH (PM2.5) DAN BUNYI DI KALANGAN PEKERJA AUTOMOTIF DAN STATUS KESIHATAN KARDIOVASKULAR MEREKA DALAM INDUSTRI PEMBUATAN KENDERAAN TERPILIH DI SELANGOR, MALAYSIA

It is a pleasure to have you as a participant in this research. The objective of this research is to assess the association between particulate matter (PM 2.5) and occupational noise among automotive workers and their cardiovascular health status in a selected automotive manufacturing industry in Selangor, Malaysia. Kindly provide your responses to all of the questions with the utmost honesty, accuracy, as completely as possible before returning this questionnaire to us. Your answers will remain confidential and will be used solely for the purpose of research. Thank you in advance for your participation in this research.

Adalah berbesar hati untuk mempunyai anda sebagai peserta dalam penyelidikan ini. Objektif penyelidikan ini adalah untuk menilai perkaitan antara bahan zarah (PM2.5) dan bunyi pekerjaan di kalangan pekerja automotif dan status kesihatan kardiovaskular mereka dalam industri pembuatan automotif terpilih di Selangor, Malaysia. Sila berikan jawapan anda kepada semua soalan dengan penuh kejujuran, ketepatan, selengkap mungkin sebelum mengembalikan soal selidik ini kepada kami. Jawapan anda akan kekal sulit dan hanya akan digunakan untuk tujuan penyelidikan sahaja. Terima kasih terlebih dahulu atas penyertaan anda dalam penyelidikan ini.

Respondent No./*Responden No.* : ☐☐
Date/*Tarikh* : ☐☐☐☐☐☐

This questionnaire has (6) printed pages including the front page. Please answer **ALL** questions. We greatly appreciate and value your valuable opinion, which is extremely important to us on a professional level.

Soal selidik ini mempunyai (6)muka surat bercetak termasuk muka depan. Sila jawab ***SEMUA*** *soalan. Kami sangat menghargai dan menghargai pendapat anda yang berharga, yang sangat penting bagi kami pada peringkat profesional.*

1

Part A : Socio-demographic and work characteristics.

Bahagian A: Maklumat latar belakang dan ciri-ciri pekerjaan.

Instruction : Please select the appropriate answer option by marking the box with a tick (/) and fill in the blanks for the following questions.

Arahan : Sila pilih pilihan jawapan yang sesuai dengan menandakan kotak dengan tanda (/) dan isikan tempat kosong untuk soalan-soalan berikut.

1. Age (*Umur*) : ______________
2. Gender (*Jantina*) : ☐ Male/*Lelaki* ☐ Female/ *Perempuan*
3. If female, are you currently pregnant?
   - ☐ Yes (*Ya)*
   - ☐ No (*Tidak)*
4. Nationality (*Kewarganegaraan*) : ☐ Malaysian/ *Warganegara*
   ☐ Non-Malaysia/*Bukan warganegara*
5. Smoking status (*status merokok*):
   - ☐ Yes/*Ya*
   - ☐ No/ *Tidak*
   - ☐ Ex-smokers/ *bekas perokok*
6. Weight (*Berat*) : _______Kg
7. Height (*Tinggi*) : _______Cm
8. Work characteristics *(Ciri-ciri pekerjaan)*
   - I. Job title (*Jawatan Pekerjaan*): ________
   - II. Work unit (*Unit kerja*): ________
   - III. Period of employment (*Tempoh tahun* pekerjaan) : __________
   - IV. Shift work (*Kerja syif*) : ☐ Yes/ Ya ☐ No/*Tidak*
   - V. Number of hours spend at the main work station : _________ hours/*jam*
     (*Bilangan jam bekerja di stesen kerja utama*)
   - VI. Working days per week *(Hari bekerja dalam seminggu)* : _________ days /*hari*

2

Part B: Indoor Air Quality (IAQ) Assessment

Bahagian B: Penilaian kualiti udara dalaman

9. Has your Company carried out any assessment related to IAQ?
(*Adakah tempat kerja anda telah menjalankan sebarang penilaian berkaitan IAQ?*)

☐Yes/ *Ya* ☐No/ *Tida* ☐In progress/*sedang berjalan* ☐Not sure/*Tidak pasti*

10. Have you been bothered during the last three (3) months by any of the following factors at your workstation/workplace?. Tick (/) which you may feel appropriate based on your current situation (*Pernahkah anda terganggu dalam tempoh tiga (3) bulan lepas oleh mana-mana faktor berikut di stesen kerja/tempat kerja anda? Tandakan (/) yang anda rasa sesuai berdasarkan situasi semasa anda)*

No	**Present symptoms** (*Gejala-gejala yang sedang dialami)*	**Yes, everyday** (*Ya, setiap hari)*	**Yes sometimes (2-3 times a week)** [Ya, selalu (2-3 kali seminggu)]	**No, never** (*Tidak pernah*)	**If yes, do you believe that is due to your work environment?** Jika ya, adakah anda percaya ia disebabkan oleh persekitaran kerja anda?	
					Yes/ *Ya*	**No/ *Tidak***
1	Fatigue heavy-headed *(Rasa berat kepala)*					
2	Fatigue/lethargy *(keletihan/ lesu)*					
3	Drowsiness *(rasa mengantuk)*					
4	Irritation of the eyes *(Kerengsangan mata)*					
5	Skin rashes / itchiness *(Ruam pada kulit/ gatal-gatal)*					
6	Irritated, stuffy nose *(Hidung tersumbat/ merengsa)*					
7	Hoarse/ dry throat (*Tekak serak/ kering)*					
8	Headache *(Pening kepala)*					

3

11. No. of days in the past one (1) month that you had to take off work because of these complaints: _____days

(*Bilangan hari dalam satu (1) bulan lalu yang anda terpaksa berhenti kerja kerana aduan ini:* ____*Hari*)

12. When do these complaints occur? (*Bilakah aduan ini berlaku?*)
    - ☐ Mornings (*Pagi*)
    - ☐ Afternoons (*Tengah hari*)
    - ☐ No noticeable trend (*Tiada trend yang ketara*)

13. When do you experience relief from these complaints? (*Bilakah anda mengalami kelegaan daripada aduan ini?*)
    - ☐ After I leave my workstation (*Selepas saya meniggalkan stesen kerja saya)*
    - ☐ After I leave the building (*Selepas saya meninggalkan bangunan)*
    - ☐ No noticeable trend (*Tiada trend yang ketara*)

14. Are you disturbed or annoyed due to poor indoor air quality at the workplace?

    (Adakah anda terganggu atau terganggu kerana kualiti udara dalaman yang lemah di tempat kerja?)
    - ☐ Yes *(Ya)*
    - ☐ No *(Tidak)*

Part C : Noise exposure

Bahagian C: Pendedahan bunyi

15. Do noise levels prevent conservation with co-workers in a normal voice level when at work ?

    (Adakah tahap bising menghalang komunikasi anda dengan rakan sekerja anda semasa dalam tahap suara yang biasa semasa di tempat kerja?)
    - ☐ Yes *(Ya)*
    - ☐ No *(Tidak)*

16. Do you have trouble following conversation with 2 or more people talking at the same time

    (Adakah anda menghadapi masalah mengikuti perbualan dengan 2 orang atau lebih yang bercakap pada masa yang sama?)
    - ☐ Yes *(Ya)*. Please specify *(Sila nyatakan)*:_____________
    - ☐ No *(Tidak)*

17. Have you noticed ringing or a temporary reduction in hearing after work?

    (Adakah anda perasan deringan atau pengurangan sementara dalam pendengaran selepas bekerja?)
    - ☐ Yes *(Ya)*
    - ☐ No *(Tidak)*

4

18. Do you regularly engaged in a noisy hobbies such as use of motorcycles, power tools, firearms, or loud music?

(Adakah anda kerap terlibat dalam hobi yang bising seperti menggunakan motosikal, alatan kuasa, senjata api atau muzik yang kuat?)

☐ Yes *(Ya)*

☐ No *(Tidak)*

19. Do you currently use hearing protection?

(Adakah anda menggunakan perlindungan pendengaran pada masa ini?)

☐ Yes *(Ya)*. If yes, which *(Jika ya, yang mana satu):*

 ☐ Ear plug (*penyumbat telinga)*

 ☐ Ear muff *(penutup telinga)*

☐ No *(Tidak)*

20. Are you disturbed or annoyed due to noise at the workplace ?

(Adakah anda terganggu atau terganggu kerana bunyi bising di tempat kerja?)

☐ Yes *(Ya)*

☐ No *(Tidak)*

Part D: Cardiovascular health status

Bahagian D: Status kesihatan kardiovaskular

21. Do you have any family history of cardiovascular-related diseases?

Adakah anda mempunyai sejarah keluarga dengan penyakit berkaitan kardiovaskular ?

☐ Yes *(Ya)*. Please specify *(Sila nyatakan)*: ________

☐ No *(Tidak)*

22. Have you taken any medication?

☐ Yes *(Ya)*. Please specify the name of disease or medication *(Sila nyatakan nama penyakit atau ubat)*: ________

☐ No *(Tidak)*

23. What is your body mass index? *(Apakah indeks jisim badan anda?)*

☐ Underweight, <18.5 kg/m2 ☐ Overweight, 25-30 kg/m2

☐ Normal weight, 18.5-25 kg/m2 ☐ Obese, ≥ 30 kg/m2

24. How many hours of sleep do you have on average per night?

(Berapakah jam purata anda tidur setiap malam?)

☐ 0-4 hours *(jam)* ☐ 7-8 hours *(jam)*

☐ 5-6 hours *(jam)* ☐ More than 8 hours *(lebih daripada 8 jam)*

5

25. Did you perform night shift work yesterday?

(Adakah anda melakukan kerja syif malam semalam?)

☐ Yes *(Ya)*

☐ No *(Tidak)*

26. Have you ever been diagnosed with any of the diseases below?. If Yes, tick (/) *[Adakah anda pernah disahkan menghidap mana-mana penyakit dibawah ini? Jika ya, tandakan (/)]*

Diseases (Penyakit-penyakit)	**Yes *(Ya)***	**No *(Tidak)***
Diabetes (Kencing manis)		
Hypertension (Darah tinggi)		
Hypercholesterolemia (Hiperkolesterolemia)		

27. Have you ever experienced any of the following symptoms in the past year? Tick (/) if you ever experience the symptoms below.

(Adakah anada pernah mengalami mana-mana gejala berikut dalam setahun yang lepas? Tanda (/) jika anda pernah mengalami gejala-gejala berikut.)

Symptoms *(gejala)*	**Yes *(Ya)***	**No *(Tidak)***
Chest pain or discomfort *(Sakit dada atau ketidakselesaan)*		
Shortness of breath *(Sesak nafas)*		
Irregular heartbeat *(Degupan jantung tidak teratur)*		
Nausea *(Mual)*		
Vomiting *(Muntah-muntah)*		
Pain, weakness or numbness in the leg or arms if the blood vessels in those area are narrowed *(Sakit, lemah atau kebas pada kaki atau lengan jika saluran darah di Kawasan tersebut disempitkan)*		

28. How often do you engage in physical activity each week?

(Berapa kerapkah anda terlibat dengan aktiviti fizikal setiap minggu?)

☐ Minimum 30 min/day, 5 days/week of moderate intensity physical activity. *(Minimum 30 minit/sehari, 5 hari/seminggu aktiviti fizikal dengan intensity sederhana)*

☐ 15 min/day, 5 days/week of vigorous intensity physical activity. *(Minimum 15 minit/sehari, 5 hari seminggu aktiviti fizikal dengan keamatan tinggi)*

☐ I do not engage in any physical activity. *(Saya tidak terlibat dengan mana-mana akitiviti fizikal)*

This is the end of the question.

Ini adalah penghujung soalan.

Appendix D: Photos during monitoring

	
Picture taken during the filling out of questionnaire before they start their work shift	The worker's weight being measured for BMI calculation using weighing scale
	
Measurements of the worker's blood pressure before work	The working environment where the workers were polishing bumper parts
	
The placement of SLM during monitoring	The location of DustTrak. It was placed as near as possible to the workers' workstation

One Gasmaster Sdn Bhd 199701040621 (456121-K)
18, Jalan PJU 3/48, Sunway Damansara Technology Park, 47810 Petaling Jaya, Selangor Darul Ehsan, Malaysia.
Tel : +6 03 7885 0202 Fax : +6 03 7885 9545 E : sales@onegasmaster.com www.onegasmaster.com

Page 2 of 2

Certificate No: AC-SLM/0711/1122 (RMA/GM4041)

Calibration Result

i. Absolute Acoustic Calibration

Nominal Sound Pressure Level (SPL)	Measured Sound Pressure Level (SPL)	
	Before Adjustment	After Adjustment
114.0 dB at 1000 Hz	104.2 dB	No Adjustment

SPL Output at 114.0 dB using reference Sound Calibrator with Calibration Uncertainty: ± 0.28 dB.

ii. Electrical Calibration

Calibration Uncertainty: ± 0.29 dB for Frequency A Weighting Test, Frequency C Weighting Test, Frequency Linear Weighting Test, Level Range Control Test, Linearity Test at 10 & 1 dB step.

iii. Internal Octave Filter Calibration

Calibration Uncertainty = ± 0.29dB.

Remarks: The results given in this certificate only relate to this calibrated item

The reported expanded measurement uncertainty is stated as the standard measurement uncertainty multiplied by the coverage factor k=2 such that the coverage probability corresponds to approximately 95%.

Appendix F: Raw data

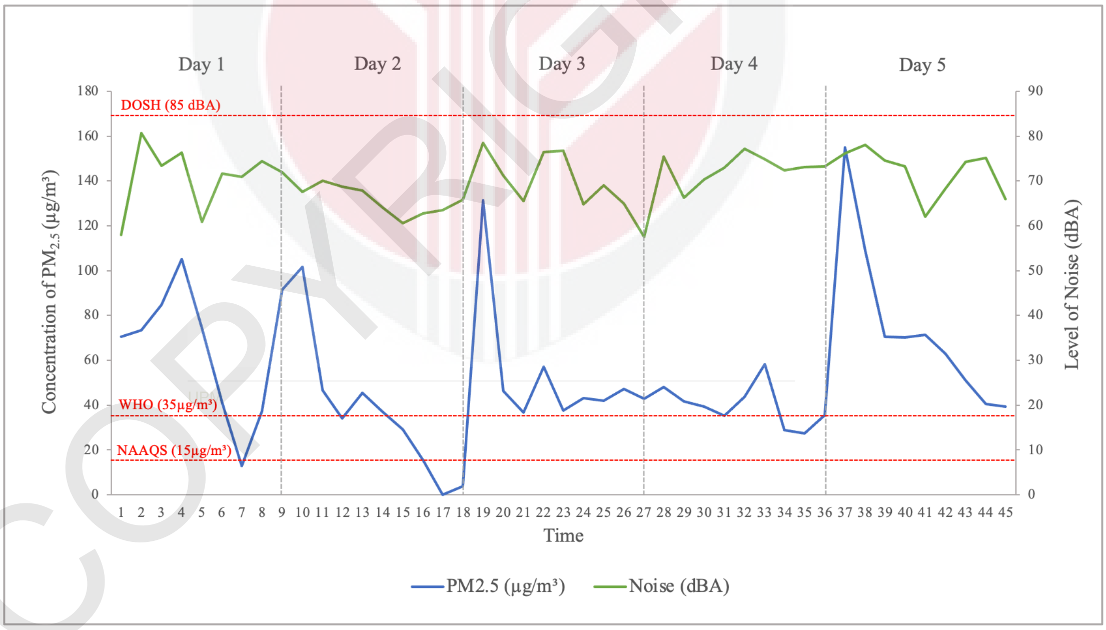
1) **Blood pressure measurement (SBP, DBP, and pulse) of the participants of before and after work.**

No	SBP (Before)	SBP (After)	DBP (Before)	DBP (After)	Pulse (Before)	Pulse (After)
1	123.7	111.7	79.3	61.3	64.0	90.7
2	128.3	129.0	78.3	65.0	91.0	74.3
3	117.7	124.7	70.0	72.0	62.0	91.7
4	118.7	108.0	74.7	61.3	74.3	71.3
5	132.7	128.0	62.0	59.3	74.7	63.7
6	109.3	106.7	56.0	47.7	67.3	74.7
7	107.3	103.7	60.0	55.7	67.3	77.7
8	126.0	133.3	76.0	73.0	87.0	87.0
9	145.3	146.7	87.0	90.7	102.0	98.0
10	134.7	128.3	67.0	55.0	78.7	51.7
11	113.7	105.0	70.3	64.0	71.7	81.3
12	112.3	110.7	79.7	71.0	82.3	84.3
13	127.3	123.7	82.0	73.7	87.3	87.3
14	124.0	112.7	91.7	85.0	105.3	117.0
15	118.7	110.0	70.7	67.7	71.7	82.0
16	143.0	129.0	84.3	75.3	88.0	78.7
17	104.3	114.3	59.3	68.3	69.7	77.7
18	119.7	106.0	61.3	54.7	74.7	70.0
19	125.3	127.3	75.0	74.3	78.7	93.7
20	126.3	123.7	79.7	69.7	77.7	80.3
21	133.0	125.0	81.3	78.0	78.3	85.0
22	124.3	129.0	62.7	67.0	71.0	72.0
23	128.3	128.3	80.3	77.0	98.3	98.7
24	133.3	132.3	79.0	74.0	76.7	91.0
25	123.7	122.0	71.7	69.7	68.3	74.0
26	134.0	129.0	63.7	61.0	68.0	56.3
27	119.3	111.7	60.3	59.0	71.3	76.0
28	110.7	106.7	58.3	57.3	67.7	60.7
29	113.7	95.7	69.3	52.3	73.7	80.7
30	112.0	100.7	68.7	59.0	60.0	75.0
31	109.0	99.3	68.0	62.0	75.7	83.3
32	108.3	101.7	49.0	45.7	75.0	77.0
33	108.3	97.7	61.0	51.7	67.0	70.7
34	104.7	94.3	68.3	56.3	80.0	80.0
35	130.3	130.3	72.3	69.7	85.0	85.3

2) **Paired sample T-test result for each of the blood pressure variables both before and after work**

Pair		t	Df	Sig. (2 tailed)
Pair 1	SBP Before work – SBP After work	4.273	34	< 0.001
Pair 2	DBP Before work – DBP After work	5.607	34	< 0.001
Pair 3	Pulse Before Work – Pulse After work	-1.640	34	0.055

3) **The concentration of $PM_{2.5}$ level and noise level for five sampling days for every hour**



Appendix G : Normality Testing

1. Normality test for sociodemographic characteristic (age)

Variable	Shapiro-Wilk Test (Sig.)	Normality
Age	<.001	Not normality distributed

2. Normality test for $PM_{2.5}$ and noise levels

The normality of a continuous data could be determined based on the value of Shapiro-Wilk Test, where a value of $p > 0.05$ indicates the data is normally distributed. Based on the table below, only the data for $PM_{2.5}$ was found to be normally distributed, while the data for noise levels was not normally distributed since $p < 0.05$. Therefore, a sign test was used to compare $PM_{2.5}$ and noise levels with their standards.

Variable	Shapiro-Wilk Test (Sig.)	Normality
$PM_{2.5}$ levels	0.237	Normality distributed
Noise levels	0.001	Not normally distributed

3. Normality test for blood pressure variables

Variable	Shapiro-Wilk Test (Sig.)	Normality
SBP Before	0.312	Normally distributed
SBP After	0.055	Normally distributed
DBP Before	0.880	Normally distributed
DBP After	0.895	Normally distributed
Pulse Before	0.025	Normally distributed
Pulse After	0.436	Normally distributed

Appendix H : Dependent T-Test

1. Dependent T test to determine whether there is a significance difference between gender and each of the blood pressure variables

T-test for 'Equal variance assumed' was used since the homogeneity of variance assumption is not violated (p >0.05) to determine whether there is a sgnificant difference between the difference of gender and the systolic blood pressure after work. Based on the table below, there is a significant difference between the difference in gender and the SBP (P <0.001).

Variable	F	Sig	Sig. (2-tailed)	Mean Difference	SE Difference	95% CI
SBP After	0.293	0.592	**<0.001**	16.73	3.91	8.77 – 24.69
DBP After	0.039	0.844	0.237	4.45	3.70	-3.07 – 12.00
Pulse After	1.204	0.281	0.285	-4.91	4.53	-14.12 – 4.30

Appendix I : ANOVA Test

1. ANOVA test between difference of BMI and blood pressure variables

SBP

Based on the figure below, p <0.05 showing that there is a significance difference between the four groups of BMI; hence, further post hoc is necessary to determine which specific group that have significant relationship with the SBP (after work).

ANOVA

SBP_After

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1430.267	3	476.756	3.292	.033
Within Groups	4489.682	31	144.828		
Total	5919.950	34			

After Post Hoc Test was conducted, it was found that there is a significant difference between the underweight and overweight group of BMI with SBP

Post Hoc Tests

Multiple Comparisons

Dependent Variable: SBP_After
Tukey HSD

(I) BMI	(J) BMI	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Underweight, <18.5 kg/m2	Normal weight, 18.5-25 kg/m2	-18.8808	7.4510	.074	-39.103	1.342
	Overweight, 25-30 kg/m2	-24.7733*	8.0230	.021	-46.548	-2.998
	Obese, ≥ 30 kg/m2	-14.5533	9.8261	.461	-41.222	12.115
Normal weight, 18.5-25 kg/m2	Underweight, <18.5 kg/m2	18.8808	7.4510	.074	-1.342	39.103
	Overweight, 25-30 kg/m2	-5.8925	4.8305	.619	-19.003	7.218
	Obese, ≥ 30 kg/m2	4.3275	7.4510	.937	-15.895	24.550
Overweight, 25-30 kg/m2	Underweight, <18.5 kg/m2	24.7733*	8.0230	.021	2.998	46.548
	Normal weight, 18.5-25 kg/m2	5.8925	4.8305	.619	-7.218	19.003
	Obese, ≥ 30 kg/m2	10.2200	8.0230	.586	-11.555	31.995
Obese, ≥ 30 kg/m2	Underweight, <18.5 kg/m2	14.5533	9.8261	.461	-12.115	41.222
	Normal weight, 18.5-25 kg/m2	-4.3275	7.4510	.937	-24.550	15.895
	Overweight, 25-30 kg/m2	-10.2200	8.0230	.586	-31.995	11.555

*. The mean difference is significant at the 0.05 level.

DBP

ANOVA

DBP_After

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	865.552	3	288.517	3.328	.032
Within Groups	2687.514	31	86.694		
Total	3553.066	34			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: DBP_After
Tukey HSD

(I) BMI	(J) BMI	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Underweight, <18.5 kg/m2	Normal weight, 18.5-25 kg/m2	-15.5265	5.7648	.052	-31.173	.120
	Overweight, 25-30 kg/m2	-19.1100*	6.2073	.021	-35.957	-2.263
	Obese, ≥ 30 kg/m2	-18.5567	7.6024	.090	-39.190	2.077
Normal weight, 18.5-25 kg/m2	Underweight, <18.5 kg/m2	15.5265	5.7648	.052	-.120	31.173
	Overweight, 25-30 kg/m2	-3.5835	3.7373	.773	-13.727	6.560
	Obese, ≥ 30 kg/m2	-3.0302	5.7648	.952	-18.676	12.616
Overweight, 25-30 kg/m2	Underweight, <18.5 kg/m2	19.1100*	6.2073	.021	2.263	35.957
	Normal weight, 18.5-25 kg/m2	3.5835	3.7373	.773	-6.560	13.727
	Obese, ≥ 30 kg/m2	.5533	6.2073	1.000	-16.294	17.400
Obese, ≥ 30 kg/m2	Underweight, <18.5 kg/m2	18.5567	7.6024	.090	-2.077	39.190
	Normal weight, 18.5-25 kg/m2	3.0302	5.7648	.952	-12.616	18.676
	Overweight, 25-30 kg/m2	-.5533	6.2073	1.000	-17.400	16.294

*. The mean difference is significant at the 0.05 level.

Pulse

Based on the figure below, p >0.05 indicating that there are no significant difference between the difference of BMI with pulse; therefore, post hoc was not necessary to be run.

ANOVA

Pulse_After

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	120.268	3	40.089	.235	.871
Within Groups	5109.051	30	170.302		
Total	5229.320	33			

2. ANOVA test between difference of age group and blood pressure variables

ANOVA test was carried out to deterine eitherdifferences of age group could influence the blood pressure variables (SBP, DBP, and pulse). The ANOVA test results below shows

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Systolic Blood Pressure measurement before work	Between Groups	721.174	3	240.391	2.325	.094
	Within Groups	3205.845	31	103.414		
	Total	3927.019	34			
Systolic Blood Pressure measurement after work	Between Groups	1403.404	3	467.801	3.211	.036
	Within Groups	4516.545	31	145.695		
	Total	5919.950	34			
Diastolic Blood Pressure measurement before work	Between Groups	431.195	3	143.732	1.581	.214
	Within Groups	2817.466	31	90.886		
	Total	3248.661	34			
Diastolic Blood Pressure measurement after work	Between Groups	545.777	3	181.926	1.875	.154
	Within Groups	3007.289	31	97.009		
	Total	3553.066	34			
Pulse before work	Between Groups	389.286	3	129.762	1.132	.351
	Within Groups	3552.687	31	114.603		
	Total	3941.973	34			
Pulse afetr work	Between Groups	159.125	3	53.042	.321	.810
	Within Groups	5121.181	31	165.199		
	Total	5280.306	34			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Group_age	(J) Group_age	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Systolic Blood Pressure measurement before work	10–19	20–29	-.1994	6.2007	1.000	-17.029	16.630
		30–39	13.8083	7.7669	.303	-7.272	34.888
		40–49	5.7233	9.2832	.926	-19.472	30.919
	20–29	10–19	.1994	6.2007	1.000	-16.630	17.029
		30–39	14.0077	5.4618	.069	-.816	28.831
		40–49	5.9227	7.4622	.857	-14.330	26.176
	30–39	10–19	-13.8083	7.7669	.303	-34.888	7.272
		20–29	-14.0077	5.4618	.069	-28.831	.816
		40–49	-8.0850	8.8069	.795	-31.987	15.817
	40–49	10–19	-5.7233	9.2832	.926	-30.919	19.472
		20–29	-5.9227	7.4622	.857	-26.176	14.330
		30–39	8.0850	8.8069	.795	-15.817	31.987
Systolic Blood Pressure measurement after work	10–19	20–29	2.6769	7.3599	.983	-17.298	22.652
		30–39	21.9450	9.2189	.102	-3.076	46.966
		40–49	9.4500	11.0187	.826	-20.456	39.356
	20–29	10–19	-2.6769	7.3599	.983	-22.652	17.298
		30–39	19.2681*	6.4829	.028	1.673	36.863
		40–49	6.7731	8.8573	.870	-17.266	30.812
	30–39	10–19	-21.9450	9.2189	.102	-46.966	3.076
		20–29	-19.2681*	6.4829	.028	-36.863	-1.673
		40–49	-12.4950	10.4533	.634	-40.866	15.876
	40–49	10–19	-9.4500	11.0187	.826	-39.356	20.456
		20–29	-6.7731	8.8573	.870	-30.812	17.266
		30–39	12.4950	10.4533	.634	-15.876	40.866

3. ANOVA test between difference of age group and blood pressure variables

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Systolic Blood Pressure measurement before work	Between Groups	905.581	2	452.790	4.795	.015
	Within Groups	3021.438	32	94.420		
	Total	3927.019	34			
Systolic Blood Pressure measurement after work	Between Groups	1611.955	2	805.978	5.987	.006
	Within Groups	4307.995	32	134.625		
	Total	5919.950	34			
Diastolic Blood Pressure measurement before work	Between Groups	69.600	2	34.800	.350	.707
	Within Groups	3179.061	32	99.346		
	Total	3248.661	34			
Diastolic Blood Pressure measurement after work	Between Groups	110.790	2	55.395	.515	.602
	Within Groups	3442.276	32	107.571		
	Total	3553.066	34			
Pulse before work	Between Groups	96.851	2	48.426	.403	.672
	Within Groups	3845.122	32	120.160		
	Total	3941.973	34			
Pulse afetr work	Between Groups	155.731	2	77.866	.486	.619
	Within Groups	5124.575	32	160.143		
	Total	5280.306	34			

Post Hoc Tests

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Smoking status of workers	(J) Smoking status of workers	Mean Difference (I−J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Systolic Blood Pressure measurement before work	Yes	No	9.8119*	3.4355	.020	1.370	18.254
		Ex-smokers	-2.1200	6.1135	.936	-17.143	12.903
	No	Yes	-9.8119*	3.4355	.020	-18.254	-1.370
		Ex-smokers	-11.9319	6.1135	.141	-26.955	3.091
	Ex-smokers	Yes	2.1200	6.1135	.936	-12.903	17.143
		No	11.9319	6.1135	.141	-3.091	26.955
Systolic Blood Pressure measurement after work	Yes	No	13.9162*	4.1022	.005	3.836	23.997
		Ex-smokers	2.1785	7.2999	.952	-15.760	20.117
	No	Yes	-13.9162*	4.1022	.005	-23.997	-3.836
		Ex-smokers	-11.7377	7.2999	.257	-29.676	6.201
	Ex-smokers	Yes	-2.1785	7.2999	.952	-20.117	15.760
		No	11.7377	7.2999	.257	-6.201	29.676