DEVELOPMENT AND EVALUATION OF A HEARING CONSERVATION PROGRAM AMONG VECTOR CONTROL WORKERS

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ABSTRACT

DEVELOPMENT AND EVALUATION OF A HEARING CONSERVATION PROGRAM AMONG VECTOR CONTROL WORKERS

Noise-induced hearing loss (NIHL) is one of the highest recorded occupational disease despite being preventable. In 2018, occupational noise-induced hearing loss was the highest reported occupational disease experienced by workers in Malaysia accounting for 87.7% of all occupational diseases. The aim of this study is to develop, implement and evaluate the effectiveness of a Hearing Conservation Program (HCP) in preventing noise-induced hearing loss among vector control workers. This study is divided into two phases: development of HCP (phase 1) and implementation and evaluation of HCP (phase 2). The development phase (phase 1) included a review, interview with key stakeholders and reviewing local and international guidelines. In phase 2, the HCP was implemented and evaluated using a cluster-randomized controlled trial design. A total of 183 vector control workers from nine district health offices in the state of Perak, Malaysia were randomized to intervention or control group. The multifactorial intervention included noise exposure monitoring, noise control, proper use of hearing protection devices, training and education session, audiometric testing and hazard communication. Three strategies for NIHL prevention were identified from the review: championed by leaders, one-off training and multifactorial intervention (combination of multiple strategies). The mean age of the participants were 37.7 and 36.6 years old in the intervention and control group respectively. The majority of participants in both groups were males, Malay ethnicity, and general workers with a highest education level of secondary education. The baseline mean hearing threshold observed for the grouped frequencies (2, 3 and 4 kHz) was higher among the intervention group (24.9 dB) compared to the control group (16.1 dB) for the left ear. Similar trends were observed for the right ear with 23.6 dB (intervention) and

14.8 dB (control). As for the grouped frequencies (0.5, 1, 2 and 3 kHz) the intervention group also showed higher mean hearing threshold compared to the control group with 20.8 dB (left ear) and 22.1 dB (right ear). The baseline mean score for knowledge, attitude and practice score towards NIHL was 77.8, 75.1 and 62.9 for intervention group while the control group participants averaged 73.5, 70.7 and 71.2. After 3 months, the intervention group showed a greater reduction (0.06 dB reduction) in mean hearing threshold in the left ear for the grouped frequencies (2, 3 and 4 kHz). As for the grouped frequencies (0.5, 1, 2 and 3 kHz) both intervention and control group showed a reduction in mean hearing threshold of 1.4 dB and 2.6 dB respectively for the left ear. There was also a greater improvement in the mean score for knowledge, attitude and practice towards noise-induced hearing loss (NIHL) in the intervention group as compared to the control group but were not statistically significant. The HCP has shown to be effective in preserving hearing of vector control workers as well as improving their knowledge, attitude and practice towards NIHL.

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Keywords: noise-induced hearing loss, vector control worker, occupational exposure

ABSTRAK

PEMBANGUNAN DAN PENILAIAN PROGRAM PEMULIHARAAN PENDENGARAN DI KALANGAN PEKERJA KAWALAN VEKTOR

Kehilangan pendengaran akibat bunyi bising adalah penyakit pekerjaan paling kerap dilaporkan walaupun ianya mampu dicegah. Pada tahun 2018, hilang pendengaran akibat bunyi bising adalah penyakit pekerjaan tertinggi yang dialami oleh pekerja di Malaysia iaitu sebanyak 87.7%. Tujuan kajian ini adalah untuk membangunkan, melaksanakan dan menilai keberkesanan Program Pemuliharaan Pendengaran dalam mencegah penyakit kehilangan pendengaran akibat bunyi bising di kalangan pekerja kawalan vektor. Kajian interbahagi kepada dua fasa: fasa pembangunan (fasa 1) dan fasa pelaksanaan serta penilaian (fasa 2) Program Pemuliharaan Pendengaran. Fasa pembangunan termasuk sorotan kajian secara sistematik, temuramah dengan pihak berkepentingan dan mengkaji panduan tempatan dan antarabangsa. Dalam fasa 2, pelaksanaan dan penilaian Program Pemuliharaan Pendengaran telah dilakukan menggunakan reka bentuk kajian rambang terkawal secara kluster. Sejumlah 183 pekerja kawalan vektor dari sembilan pejabat kesihatan daerah di negeri Perak, Malaysia Peserta telah dibahagikan secara rawak kepada kumpulan intervensi atau kumpulan kawalan. Intervensi yang diberikan dalam kajian ini termasuk pemantauan bunyi bising, kawalan bunyi bising, penggunaan alat pelindung pendengaran, sesi latihan dan pendidikan, ujian saringan pendengaran atau audiomteri dan komunikasi bahaya di tempat kerja. Tiga strategi untuk pencegahan kehilangan pendengaran akibat bunyi bising telah dikenalpasti dari sorotan kajian secara sistematik: dijuarai oleh pemimpin, latihan sekali dan intervensi pelbagai faktor (gabungan pelbagai strategi). Purata umur peserta adalah 37.7 dan 36.6 tahun dalam kumpulan intervensi dan kawalan. Majoriti peserta dalam kedua-dua kumpulan adalah lelaki, etnik Melayu, dan pekerja am dengan tahap pendidikan tertinggi sekolah menengah. Purata ambang pendengaran sebelum intervensi pada frekuensi berkumpulan (2, 3 dan 4 kHz) adalah lebih tinggi dalam kumpulan intervensi (24.9 dB) berbanding dengan kumpulan kawalan (16.1 dB) untuk telinga kiri. Gambaran serupa diperhatikan untuk telinga kanan dengan 23.6 dB (intervensi) dan 14.8 dB (kawalan). Manakala bagi frekuensi berkumpulan (0.5, 1, 2 dan 3 kHz) kumpulan intervensi juga menunjukkan purata ambang pendengaran yang lebih tinggi berbanding kumpulan kawalan dengan 20.8 dB (telinga kiri) dan 22.1 dB (telinga kanan). Purata skor sebelum intevensi untuk pengetahuan, sikap dan skor amalan terhadap penyakit ini adalah 77.8, 75.1 dan 62.9 untuk kumpulan intervensi sementara peserta kumpulan kawalan purata 73.5, 70.7 dan 71.2. Selepas 3 bulan, kumpulan intervensi menunjukkan pengurangan purata ambang pendengaran yang lebih besar (pengurangan 0.06 dB) untuk frekuensi berkumpulan (2, 3 dan 4 kHz) bagi telinga kiri. Manakala bagi frekuensi berkumpulan (0.5, 1, 2 dan 3 kHz), kedua-dua kumpulan intervensi dan kawalan menunjukkan pengurangan purata ambang pendengaran sebanyak 1.4 dB dan 2.6 dB masing-masing untuk telinga kiri. Terdapat juga peningkatan yang lebih tinggi dalam skor purata pengetahuan, sikap dan amalan terhadap kehilangan pendengaran akibat bunyi bising dalam kumpulan intervensi berbanding kumpulan kawalan tetapi tidak signifikan. Program ini terbukti berkesan dalam memelihara pendengaran pekerja kawalan vektor serta meningkatkan pengetahuan, sikap dan amalan mereka terhadap kehilangan pendengaran akibat bunyi bising.

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Kata kunci: hilang pendengaran akibat bunyi bising, pekerja kawalan vektor, pendedahan dari pekerjaan

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LIST OF SYMBOLS AND ABBREVIATIONS

ADBA	:	Audiometric Database Analysis
AF	:	Attributable Fraction
ANSI	:	American National Standards Institute
ASEAN	:	Association of Southeast Asian Nations
CBA	:	Controlled Before-After
COEHUM	:	Centre of Occupation and Environment Health
CI	:	Confidence Interval
CINAHL	:	Cumulative Index to Nursing and Allied Health Literature
DALY	:	Disability-Adjusted Life Years
dB	:	Decibels
DHO	:	District Health Office (DHO)
DOSH	:	Department of Occupational Safety and Health
EHF	:	Extended High-Frequency
FMA	:	Factories and Machinery Act
HBM	:	Health Belief Model
HCP	:	Hearing Conservation Program (HCP)
HI	:	Hearing Impairment
HIRARC	:	Hazard Identification, Risk Assessment and Risk Control
HL	:	Hearing Loss
HPD	:	Hearing Protection Devices
Hz	:	Hertz
ICC	:	Intracluster Correlation Coefficient
ITS	:	Interrupted Time Series
kHz	:	Kilohertz

KAP : Knowledge, Attitude and Practice

MOH : Ministry of Health

NCD : Non-Communicable Diseases

NHMRC : National Health and Medical Research Council

NHMS : National Health and Morbidity Survey

NIHL : Noise-Induced Hearing Loss

NIOSH : National Institute of Occupational Safety and Health

NIDDM : Non-Insulin Dependent Diabetes Mellitus

OHD : Occupational Health Doctors

OSH : Occupational Safety and Health

OSHA : Occupational Safety and Health Act

OHC : Outer Hair Cells

PICO : Population, Intervention, Comparison and Outcomes

PTS : Permanent Threshold Shift

PEL : Permissible Exposure Limit

PP : Per-Protocol

PPE : Personal Protective Equipment

RCT : Randomized Controlled Trial

RM : Ringgit Malaysia

SD : Standard Deviation

SFF : Sustainable Farm Families

SNHL : Sensorineural Hearing Loss

SOCSO : Social Security Organization

SPSS : Statistical Package for Social Science

SLM : Sound Level Meter

STS : Standard Threshold Shift

TCTR	:	Thai Clinical Trials Registry
TWA	:	Time-Weighted-Average
TTS	:	Temporary Threshold Shift
ULV	:	Ultra-Low Volume
UMREC	:	University Of Malaya Research Ethics Committee
WHO	:	World Health Organization
%	:	Percentage

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Background

Noise-induced hearing loss (NIHL) is defined as high frequency hearing loss resulting from exposure to excessive noise at the workplace over a long period of time. NIHL remains a priority occupational disease in the field of occupational health (Coles, Lutman, Buffin, & Rra, 2000). According to the World Health Organization (WHO), it is estimated that more than four million disability-adjusted life years (DALY) were lost globally due to occupational noise-induced hearing loss (NIHL) and more than 16% of global deafness is attributed to occupational noise exposure". The economic impact of occupational noise-induced hearing loss cost 0.2% to 2% of gross domestic product in developed nations (Concha-Barrientos & Campbell-Lendrum, 2004). A study on the global burden of occupational NIHL in Malaysia by the World Health Organization (WHO) reported the attributable fraction (AF) of adult-onset hearing loss were highest (34%) in male adults ranging from 15 to 29 years old. The percentage of AF became smaller as the adults grew older for instance, 8% in female adults ranging from 60 to 69 years old. Up till the third quarter of 2018, the Department of Occupational Safety and Health (DOSH) Malaysia investigated a total of 3058 cases of occupational noise-induced hearing loss and it was the highest reported occupational disease experienced by workers (87.7%) compared to other diseases such as musculoskeletal disorders, skin and lung disease (Department of Occupational Safety and Health, 2018). The rising trend of NIHL in Malaysia has resulted in a significant increase of total compensation under the permanent disablement benefit from the Social Security Organisation (SOCSO) which in turn results in additional cost to the country's expenditure. The Social Security Organisation (SOCSO) reported a steady rise in the number of permanent total disablement benefit from 25,049 recipients in 2013 to 41,710 in 2017. Total payment of RM 536 million for permanent disablement benefit was issued in the year 2016 and was the highest reported (Social Security Organization, 2017). A study stated that Malaysia spent RM 7 million to compensate occupational noise-induced hearing loss (NIHL) cases from the year 2010 till 2012 and the main sectors contributing to this are the manufacturing industries, construction, electricity, gas and water sanitation services (Naadia, 2015). This economic impact due to compensation of noise-induced hearing loss acquired by workers exposed to excessive noise at the workplace not only affects the country's economy but also the finances of the affected individual and organization. The affected worker may incur additional expenses in terms of having to purchase hearing aids and loss of income due to lost workdays and this loss of wages will be compensated by the organization (Ebel, Mack, Diehr, & Rivara, 2004). Possible causal relationships have been established between accidents at the workplace and exposure to noise and noise-induced hearing loss in the industry is regarded as one of the major causes of industrial accidents. However, it is still difficult to ascertain to what level excessive noise contributes to accidents occurrences at the workplace as they are sometimes directly and indirectly linked. For example, the inability to communicate effectively, attention disruption and unable to hear warning signals due to hearing loss suffered may result in workplace accidents. Excessive noise from a machine may trigger maintenance work from a worker that increases his risk to injury depending on the type of machine and location of machine (Wilkins & Acton, 1982; Girard et al., 2009). The increased risk of accidents with exposure to noise results in lost workdays and increased cost of compensation. Hence the financial impact of occupational noise-induced hearing loss is shared across various levels from individual to organization and to the country or national level.

Besides the economic implications to the individual, organization and country in terms of compensation, noise-induced hearing loss also reduces the productivity of workers as it results in work absenteeism due to the auditory and non-auditory effects of noise (Insurance & Leigh, 2011). Although noise-induced hearing loss is classified as a non-fatal injury it still results in indirect productivity cost to the employer due to lost productivity of workers. It is clear now that the direct and indirect cost associated with noise-induced hearing loss is substantial and contributes to the overall burden of this occupational disease.

1.2 Research Problems and Public Health Significance

Noise is a known health hazard and is mostly known for its auditory effects mainly permanent irreversible damage of hair cells in the inner ear that results in hearing impairment (King & Davis, 2003). Tinnitus or sensation of ringing in the ear is a common symptom seen in patients suffering from hearing loss and is linked to psychiatric disorders such as anxiety and depression and sleep disturbance resulting in insomnia. A lack of quality sleep causes greater distress for workers causing them to be easily irritable at work that may result in violence as a result of arguments among co-workers. It is also indirectly associated with an increased risk of accidents at the workplace as the worker is unable to focus and give full attention to his or her work (Bhatt, Bhattacharyya, & Lin, 2017). However, it is important to also acknowledge the non-auditory effects of excessive noise that has been associated with physiological changes such as increased risk of cardiovascular disease, hypertension and induce psychological stress (Moore & Lusk, 1997). This in turn lowers the quality of life of the affected individual and may result in disability.

Hearing loss also gives rise to depression and social isolation caused by difficulty in communicating with family, friends and co-workers (Peterrthorne et al., 1280). Communication is a vital tool for every human being. Inability to communicate well with others prevents one from expressing themselves and building or maintaining a relationship with others. Hearing loss has a great impact on mental health and general well-being if left uncorrected. It is known to reduce the quality of life of the affected individual due to social isolation that may lead to depression. This situation not only affects the individual suffering from hearing loss but also their immediate social circle such as spouse, children and friends. Besides that hearing loss has also been associated with difficulty in speech recognition and occurrence of impaired cognitive function especially the sensory-sensorimotor function for vision, hearing and balance (Arlinger, 2003).

Various measures have been taken from a micro to macro level to prevent noise induced hearing loss. In Malaysia, at a macro level, legislations such as the Noise Regulation 1989 are in place and is enforced by the Department of Occupational Safety and Health (DOSH). Part of the legislative requirement is for a Hearing Conservation Program (HCP) to be implemented at workplaces with excessive noise (≥ 85 dB). However, the effectiveness and implementation of the program remains questionable due to the rising trend of noise-induced hearing loss (NIHL) in Malaysia especially in the industrial sector (Tahir, 2014; Department of Occupational Safety and Health, 2018). The prevalence of NIHL among vector control workers in the state of Negeri Sembilan, Malaysia was 26.5% based on a study done in 2014 by Masilamani et al (Masilamani, Rasib, Darus, & Ting, 2014). However, there is yet to be a Hearing Conservation Program (HCP) for vector control workers who are exposed to excessive noise emitted by fogging machines during fogging activities. It is vital to have an effective Hearing Conservation Program (HCP) to prevent hearing loss among our vector control workers.

1.3 Rationale

In Malaysia, fogging using ultra low volume insecticide particles remains a mainstream method for dengue control activities. The burden of dengue fever and dengue haemorrhagic fever in Malaysia is enormous as it is one of the worst affected countries with a rising trend in number of cases in the past decade from 48,846 cases in 2007 to 83,849 cases in 2017 with 177 deaths. Malaysia recorded the highest number of dengue cases in 2015 with a total of 120, 836 cases which is further explained by the incidence rate of 396.4 cases per 100,000 population and case fatality rate of 0.28%. A total of 336 dengue related deaths were recorded that year and proved to be the highest ever recorded. The number of dengue cases showed a marked rise from 43,346 cases of dengue in 2013 to 108,698 cases of dengue in 2014. In the year 2015, the state of Perak recorded the third highest number of dengue cases with 9466 confirmed cases after Selangor (63,198) and Johor (15,743) (Ministry of Health, 2015, 2017). This clearly shows that the number of dengue cases has been increasing rapidly and Selangor is affected the most with a high diseases burden for this vector borne disease. There are many factors that contribute to the dengue epidemic in Malaysia such as serotypes shifts of the dengue virus and climate changes which causes a rise in temperature, increased rainfall and relative humidity. Climate change is the most important driving force of dengue transmission and intensity in Malaysia. However, as most of these factors are beyond our control, this leaves us with intervention on environmental hygiene, vector control and changing the human behaviour. Based on this the Ministry of Health has developed the Integrated Management Strategy for dengue prevention and control program in 2011 which was adopted from the World Health Organization (WHO). One of the main methods of vector control that is widely used is chemical control using fogging of insecticides such as Malathion, Reslin and other synthetic pyrethroids (Lee et al., 2015; Mudin, 2015). The fogging activity in the country is carried out by the vector control workers of the Ministry of Health Malaysia under the Vector Borne Disease Control Unit in each state's District Health Office (DHO). In the event of an outbreak especially in states such as Selangor, Johor and Perak where the burden of disease related to the dengue virus is high, vector prevention and control activities often involves workers from other sectors such as the State Local Authority. However, this study only looks at the vector control workers from the Perak State Health Department who have been exposed to noise hazards that are emitted from the fogging machines. A previous study by Masilamani et al. (2014) reported that vector control workers in the Ministry of Health (MOH) in the state of Negeri Sembilan were exposed to noise levels above the permissible exposure limit (PEL) as stipulated under the Noise Regulation 1989 during fogging activities. This shows that vector control workers are a vulnerable population at risk for noise-induced hearing loss due to exposure to high noise levels from fogging machines during fogging activities. Hence, human resource is vital to ensure vector control activities are carried out efficiently as well as ensure good productivity at work and it is important to protect our vector control workers who are directly involved in fogging activities.

Despite the known implications of NIHL on health, safety, cost and productivity there are not many studies that have been done to study the gaps in this field especially in terms of prevention of hearing loss and effectiveness of existing hearing loss prevention programs. There are many local studies that have been conducted to determine the prevalence and associated factors of NIHL among various occupation groups such as quarry workers (57%), airport workers (33.5%), dental staff nurses (5%), traffic police personnel (80%) and vector control workers (26.5%). However, there is scarcity of research looking into preventive methods such as Hearing Conservation Programs. Some of the factors associated with NIHL includes age, duration of service, work unit, job category, previous occupational noise exposure, and current occupational noise exposure

(Daud et al., 2011; Habib, 2012; Ismail, Daud, Ismail, & Abdullah, 2013; Masilamani et al., 2014; Thomas, Mariah, Fuad, Kuljit, Hnorl, et al., 2007). Although NIHL is a highly preventable disease and Hearing Conservation Programs (HCP) are in place in the industrial sector, it remains a major occupational health problem in Malaysia and is of high public health importance.

Although audiometric testing or screening is being carried out annually for vector control workers, it alone is inadequate to prevent noise-induced hearing loss. This is can be attributed to certain components of hearing conservation programs that are not given importance such as noise exposure monitoring and hearing protection devices. Noise exposure monitoring is vital as it helps determine the appropriate noise control methods as well as suitable hearing protection devices to be provided to workers. At the moment, there lacks proper noise exposure monitoring for vector control workers and this study will help determine the noise exposure level to fogging machines. Besides that, training and education of workers is important as it serves as a means of hazard communication between employer and employee including information on noise exposure levels. This is important as providing workers with knowledge regarding the hazard that they are exposed to will help in change in behaviour in relation to safety practice. Hearing Conservation Programs (HCP) have been shown to improve knowledge, attitude and practice of workers towards prevention of noise-induced hearing loss (NIHL) (Helt, Fausti, Konrad-Martin, Wilmington, & Helt, 2006). Besides that, a higher emphasis is given to use of hearing protection devices rather than engineering controls to reduce noise exposure levels due feasibility and cost effectiveness. Hence it is important to provide proper training and education to ensure proper use and care of hearing protection devices as this will influence its performance in providing adequate hearing protection to workers. Educating workers on health effects of noise and importance of prevention will provide them with information that will change their perception and behaviour towards safety and health practice including use of hearing protection devices (Srof & Velsor-Friedrich, 2006). This Hearing Conservation Program (HCP) includes a training and education component to improve hazard communication as well as increase awareness among workers towards noise-induced hearing loss and improve safety and health practice. Another important aspect of hearing protection devices in prevention of noise-induced hearing loss is to determine whether the level of noise attenuation is achieved with the use of adequate hearing protection devices (Toivonen, Pääkkönen, Savolainen, & Lehtomäki, 2002).

A study conducted locally reported a lack of compliance towards Hearing Conservation Progams (HCP) among industries and this needs to be improved to prevent hearing loss among workers (Nor Saleha & Noor Hassim, 2006). However, at this current moment there is no existing well documented Hearing Conservation Program (HCP) for vector control workers in the Ministry of Health (MOH), Malaysia. This is an important gap that needs to be addressed. Being a preventable disease with high cost implications in terms of compensation, it is clear that not enough is being done to prevent hearing impairment among vector control workers in the MOH, Malaysia. This study will help in the development of a Hearing Conservation Program (HCP) for the prevention of hearing impairment among vector control workers in the state of Perak. This study will be a stepping stone for future guidelines or policy related to hearing loss prevention in other job sectors as well. The findings from this study will provide information regarding noise exposure levels experienced by vector control workers based on the noise assessment as well as determine suitable hearing protection devices that would provide adequate hearing protection. These findings are vital especially in promoting and advocating other public and private organizations in Malaysia to establish strategies to prevent noise-induced hearing loss.

1.4 Study objectives

1.4.1 General objectives

To develop, implement and evaluate a Hearing Conservation Program (HCP) in the prevention of noise-induced hearing loss (NIHL) among vector control workers in the state of Perak, Malaysia.

1.4.2 Specific objective

The specific objectives of this study are:

Phase 1:

i. To develop a Hearing Conservation Program for vector control workers.

Phase 2:

i. To implement a Hearing Conservation Program (HCP) for vector control workers.
ii. To determine the effectiveness of a Hearing Conservation Program (HCP) in preventing or reducing audiometric threshold changes among vector control workers.
iii. To determine the effectiveness of a Hearing Conservation Program (HCP) in increasing knowledge, attitude and practice (KAP) towards noise-induced hearing loss (NIHL) among vector control workers.
iv. To describe the socio-demographic characteristics and noise exposure level of vector control workers during fogging activities.

1.4.3 Hypothesis

1.4.3.1 Null hypothesis

This Hearing Conservation Program (HCP) is not effective in the prevention of noise-induced hearing loss (NIHL) among vector control workers.

1.4.3.2 Alternative hypothesis

This Hearing Conservation Program (HCP) is effective in the prevention of noise-induced hearing loss (NIHL) among vector control workers.

1.5 Thesis contributions

One of the components of the Hearing Conservation Program (HCP) is noise assessment which will provide vital information regarding noise exposure levels of vector control workers during handling of fogging machines. In the field of occupational health, risk assessment is important as information regarding risk is necessary when planning appropriate control methods. Hence this study will contribute vital information on risk assessment and feasible noise control methods in relation to fogging activity that can be translated into future guidelines.

The main contribution of this thesis is the development of a comprehensive Hearing Conservation Program (HCP) catered specifically for vector control workers to prevent noise-induced hearing loss in the long term. Besides that evidence on the effectiveness of this program in preventing or reducing audiometric threshold changes will benefit future development of other hearing loss prevention programs in various job sectors where workers are exposed to noise hazard. The training and education module that is part of this Hearing Conservation Program (HCP) can be incorporated in safety and health training for workers especially in improving knowledge, attitude and practice towards noise-induced hearing loss.

CHAPTER 2: LITERATURE REVIEW

2.1 Noise-induced hearing loss (NIHL)

2.1.1 Anatomy and physiology of hearing

The human ear can be divided into three parts, which are the outer, middle and inner ear. The external ear consists of the pinna and the external ear canal and its main function is to transmit sound to the middle ear. The middle ear is an air-filled cavity in the temporal bone that is connected to the nasopharynx via the Eustachian tube. The main function of this tube is to equalize the air pressure between the outer and middle ear. The three ossicle bones in the middle ear are known as malleus, incus and stapes that transmit sound waves from the outer ear to the inner ear. The inner ear is made up of the cochlea which is a coiled tube and contains the organ of Corti which is the structure that contains the hair cells which are the auditory receptors. Besides that, the inner ear is also made up of the semicircular canals and vestibule which are vital in maintaining balance (Ganong, 2003).

2.1.2 Definition of occupational noise-induced hearing loss

Occupational Noise-Induced Hearing Loss (NIHL) is defined by the American College of Occupational and Environmental Medicine's Task Force as permanent hearing impairment as a result of prolonged exposure to high levels of noise. There are three basic types of hearing loss which are conductive hearing loss, sensorineural hearing loss and mixed hearing loss. Occupational Noise-induced hearing loss (NIHL) is a sensorineural type of hearing loss that often affects the higher frequencies (3 kHz to 6 kHz) and develops gradually as a result of chronic exposure to excessive sound levels. It often affects bilateral ears, however in some instances of exposure to impulsive noise (> 140 dB), it may cause acoustic trauma that can lead to loss of hearing on only one side. One of the early signs seen in the audiogram is a 'notching' at high frequencies (3 kHz and 6 kHz) with recovery at 8kHz (Kirchner et al., 2012b).

2.1.3 Mechanism of noise-induced hearing loss and effects on health

Noise-induced hearing loss is the second most common form of sensorineural hearing deficit after presbycusis (age related hearing loss). The pathophysiology by which noise-induced hearing loss occurs is explained by the impact of excessive noise particularly when the sound level is higher than 85 dB (A), depending on the duration and systematic exposure. It is a chronic disease that involves damage to the sensory or stereocilia hair cells in the organ of Corti resulting in irreversible damage or permanent impairment. Despite being irreversible, it is highly preventable if appropriate preventive and control measures are in place. This study is concerned with the long term effect of noise exposure on hearing. People who are at high risk of hearing loss (exposure to excessive noise) should be screened and when hearing loss is suspected, a thorough history especially occupational history, physical examination and audiometry should be performed. An audiometry with a 'notch' at 4 kHz with better hearing at both lower and higher frequencies is typical of noise-induced hearing loss and if these examinations disclose evidence of hearing loss, a full audiologic evaluation is recommended (Rabinowitz, 2000).

Occupational noise-induced hearing loss (NIHL) remains a significant problem in the world, despite substantial research on the mechanisms of damage, availability of standards for acceptable noise exposure levels and implementation of hearing conservation programs. There are also othere causes of hearing loss can besides excessive noise. For example trauma that perforates the tympanic membrane from the following mechanisms such as direct blows and foreign bodies such as sparks when welding or from hot objects. Commercial divers are at high risk of developing barotrauma which is an injury caused by a change in air pressure that typically affects the ear and lung. However excessive exposure to noise remains the most common cause of preventable hearing loss in the world. Excessive noise that is potentially hazardous can be defined as prolonged exposure to sounds of more than 85 dB (A). However, factors that determine the total amount of sound exposure is the most important and includes level of exposure (dose-response relationship) and length or duration of exposure. Typically, for exposure to sound levels in the low nineties decibels for a Time-Weighted-Average (TWA) of 8 hours, the hearing mechanism especially the hair cells tends to fatigue and results in a temporary threshold shift (TTS). This is due to the excessive metabolic stress placed upon them and hearing becomes less acute. TTS is usually temporary, transient or reversible and complete recovery ensues after sufficient rest. This condition is often caused by exposure to intense and/or loud sounds or noise for a shorter or longer time. People who experience a temporary threshold shift may often also experience temporary tinnitus. There is a point however in which moderate TTS may progress to a longer term TTS and this critical point corresponds well with the damage to the outer hair cells (OHC) through a process of damage and scarring or repair. It is given that the threshold for TTS is between 78 dB (A) and 85 dB (A) and the critical point for change from moderate TTS to long-term TTS is about 140 dB. This is of course, taking into account the spectrum of sound and duration of exposure.

If the case of TTS progresses to a couple of days, the recovery is incomplete and it results in what is known as a permanent threshold shift (PTS). This is because with persistent exposure to excessive noise, the fatigue hair cells can end up being damaged and this results in PTS. The insult in PTS involves permanent insult to the OHC in the basilar part of the cochlea which is the area that responds to 4 kHz and the adjacent areas of 3 kHz and 6 kHz. This results in irreversible damage to the hair cells causing permanent hearing loss. This part of the ear is known as the most sensitive part because of the harmonic amplification of the ear canal and also because of absolute sensitivity. An audiometric evaluation will show classic ‘dip’ or ‘notch’, usually maximal at 4 kHz but may also occur anywhere between 3 kHz and 6 kHz. The exposure to higher sound levels and longer durations will result in hearing loss extending into adjacent frequencies. If the intensity of the sound is high, it may produce a more severe TTS which can progress more rapidly to become PTS (Alberti, 2001).

Besides the auditory effects of noise as mentioned in the paragraphs above, noise also has non auditory effects on behaviour and health. It has been shown to cause narrowing of attention during tasks and is likely to affect performance adversely. In an industrial setting it can result in poor product reliability and increase the potential of accidents in work settings. Existing studies also suggest the exposure to excessive noise can cause psychological effects and serious mental distress such as increased anxiety and emotional stress. Exposure to high-intensity sound of 110 dB (A) or above has been associated with nervousness, sleep difficulties, nausea, headaches, instability, gastrointestinal effects, argumentativeness, sexual impotency and changes in general mood. Long-term work under high-intensity sound is associated with at least a 60 percent increase in risk of cardiovascular diseases (Cohen & Weinstein, 1981).

2.1.4 Prevalence of noise-induced hearing loss

A study done by Nelson et al. to assess the global burden NIHL reported the worldwide morbidity of occupational NIHL in the year 2000. The worldwide burden attributed to occupational NIHL is 16%, ranging from 7% to 21% in the Western Pacific region and this burden is relatively higher compared to the developed regions of the world. In Brazil, the prevalence of NIHL was 49% among workers in the printing sectors that is possibly attributed to exposure of organic solvent as well (Nelson Imel, Nelson, Concha-Barrientos, & Fingerhut, 2006).

Based on a previous study done by Masilamani et al. in 2012 in the state of Negeri Sembilan, the prevalence of NIHL among vector control workers was shown to be 26.5% (Masilamani et al., 2014). In the study by Tahir et al. in 2014 that looked into the burden of NIHL among manufacturing and industrial workers in Malaysia, the risk of NIHL and incidence per 100,000 manufacturing workers was projected at 8% and it was estimated that 103,000 workers were potentially affected by NIHL in Malaysia. NIHL was reported to be prevalent in three sectors that were the motor vehicle parts industry (32%), tobacco industry (23%) and fabricated metal industry (23%). This study shows that NIHL is a major burden among industrial workers in Malaysia (Tahir, 2014). In another study by Ismail *et al.* on knowledge, attitude and practice of quarry workers in the state of Kelantan with relation to NIHL, it was reported that the prevalence of quarry workers with NIHL was 57%. Based on studies conducted in other industries, the prevalence of NIHL varied between 16% and 83%. The factors associated with NIHL among workers in these industries included smoking, age, noise exposure level, duration of work and poor safety practices at the workplace involving use of Hearing Protection Devices (Ismail et al., 2013). A study done among airport workers at an airport in the state of Selangor revealed a prevalence of hearing loss of 33.5% (Habib, 2012). Another study conducted among traffic personnel in Kuala Lumpur who are exposed to excessive noise from the traffic reported a prevalence of 80% however the sample size for this study was relatively small with only 30 participants (Thomas, Mariah, Fuad, Kuljit, & Philip, 2007). There was also a study that looked into prevalence of NIHL among dental staff nurses who are exposed to noise from dental instruments and found the prevalence of NIHL to be 5% (Daud et al., 2011).

2.1.5 Factors associated with sensorineural hearing loss

2.1.5.1 Smoking

In a study by Cruickshanks et al., smokers without a history of occupational noise exposure were 1.69 times more likely to have hearing loss compared to non-smokers (Cruickshanks et al., 1998). Sharabi et al found that people with a history of smoking were 1.75 times more likely to develop sensorineural hearing loss and smokers are 2.16 times more likely to develop sensorineural hearing loss (Sharabi, Reshef-Haran, Burstein, & Eldad, 2002). The pathophysiology of smoking causing sensorineural hearing loss cannot be explained using epidemiological data, however the vascular changes (vasoconstriction), increased blood viscosity and reduced oxygen carrying capacity due to smoking results in cochlear hypoxia. This is the mechanism by which smoking could cause sensorineural hearing loss (Ferrite & Santana, 2005).

2.1.5.2 Diabetes mellitus

Several studies have been done to investigate the possibility of diabetes mellitus as a risk factor for sensorineural hearing loss and most of them hypothesise that this is due to the microvascular complications of diabetes mellitus. The study by Wackym et al. found that diabetes mellitus results in higher risk of sensorineural hearing loss and this was due to the microangiopathic involvement of the endolymphatic sac and/or basilar membrane vessels resulting in cochlear ischemia. Another study by Aimoni *et al.* that looked into cardiovascular risk factors and idiopathic sudden sensorineural hearing loss (ISSNHL) showed that 15.6% of the cases suffered from diabetes mellitus (Ellerbeck, 2009; Kakarlapudi, Sawyer, & Staecker, 2003; Quilty, Godfrey, & Kennedy, 2010;

Wackym & Linthicum, 1986). In the study by Ishii et al, people with a history of non-insulin dependent diabetes mellitus (NIDDM) were 3.9 times more likely to develop noise-induced hearing loss (Ishii, Talbott, Findlay, D'Antonio, 1992).

2.1.5.3 Mumps infection

Studies have stated that viral infections such as mumps, rubella and varicella zoster infection cause sudden onset sensorineural hearing loss and this has well been well established by many studies (Hashimoto, Fujioka, & Kinumaki, 2009; Kawashima et al., 2005; Schreiber, Agrup, Haskard, & Luxon, 2010). In a systematic review by Chau et al. looking at factors associated with sudden sensorineural hearing loss, infectious disease accounted for the second highest cause of sudden hearing loss after idiopathic causes (Chau, Lin, Atashband, Irvine, 2010).

2.1.5.4 Diving

Sudden change of pressure when ascending to the surface during diving causes pressure difference between the inner ear and middle ear resulting in inner ear barotrauma. Many studies have shown increased risk of sensorineural hearing loss among divers and the relationship is well established (Schreiber et al., 2010).

2.1.5.5 Ototoxic Drugs

Many studies have looked into adverse effects of ototoxic drugs particularly causing noise-induced hearing loss. Drugs such as aminoglycosides antibiotics, streptomycin and cisplatin have been well documented to produce ototoxicity in human. The ototoxicity effect of the drugs causes destruction of the auditory receptors in the cochlea (hair cells) which results in sensorineural hearing loss (Brummett & Fox, 1989; Schacht, Talaska, & Rybak, 2012).

2.2 Vector control workers and fogging machines

Vector control workers are exposed to health and safety hazards when carrying out fogging activities mainly chemical hazards from the use of pesticides and physical hazards due to exposure to noise form the fogging machines. Both of which can be deleterious to their hearing. Protecting the vector control workers from these hazards at their workplace is important to ensure sustainability of an adequate healthy work force. Reducing the morbidity of these workers from work-related diseases such as NIHL will also be cost effective in the long run because unnecessary expenditure on healthcare and compensation can be reduced.

The job of a vector control worker includes many tasks including inspection of facilities for presence of breeding sites, conduct source reduction and respond to public complaints especially during outbreaks and operating a variety of specialized vector control equipment. One of the job scopes of a vector control worker that is of concern in this study is space spraying especially during epidemic outbreaks of dengue. Space spraying involves spreading of microscopic droplets of pesticide into the atmosphere using thermal fogging and Ultra Low Volume (ULV) fogging machines. The thermal fogging machine uses heat to vaporize the fogging solution which contains organophosphate pesticides and diesel and spray out particles with an average size from 0.5-10 micron range. The ULV fogging machine operates using cold fogging techniques and is equipped with motors that produce a high power, low pressure air steam to produce larger sized particles as compared to thermal fogging, averaging from 5-30 micron range. Fogging activities are normally carried out between 5pm till 8 pm and the frequency at which space spraying is carried out is three cycles for every case that is notified but it also depends on the incidence of dengue fever in that area. The fogging machines emit noise levels of more than 90 dB (A) at a distance of 0.5m and the vector control workers are provided with PPE such as respirators, goggles, gloves, and hearing protection devices. Due to the high levels of noise emitted by the fogging machines used in vector control which is above the permissible exposure limit (PEL) of 90 dB (A) for continuous sound, the Factory and Machinery Act 1967 requires the vector control workers to undergo a yearly audiometric testing. Besides that, vector control workers are also exposed to organophosphates pesticides and diesel, which increases risk of hearing loss. These chemicals have ototoxic properties which increases the likelihood of vector control workers having a higher likelihood of developing NIHL (Masilamani et al., 2014).

2.3 Legislation related to noise in Malaysia

In Malaysia, exposures in the workplace are regulated under two main acts known as the Factories and Machinery Act (FMA) 1967 and Occupational Safety and Health Act (OSHA) 1994. Both these acts are enforced by the Department of Occupational Safety and Health (DOSH) Malaysia. The OSHA 1994 consists of regulations, code of practices and guidelines that serve as further provisions for securing the safety, health and welfare of persons at work, for protecting others against risks to safety and health in connection with the activities of persons at work, to establish the National Council for Occupational Safety and Health, and for matters connected therewith (Occupational Safety and Health Act and Regulations 1994, 2014). The Factories and Machinery (FMA) 1967 is an act to provide for the control of factories with respect to matters relating to the safety, health and welfare of persons therein, the registration and inspection of machinery and for the matters connected therewith. Hazardous noise at the workplace is regulated under the Factories and Machinery Act 1967 – Noise Regulation 1989. This regulation aims to protect workers from excessive noise while at work and to prevent workers from being affected by NIHL. Hearing impairment is defined under this regulation as an arithmetic average of the permanent hearing threshold level of an employee at 500, 1000, 2000 and

3000 Hz , which is shifted by 25 dB or more compared to the standard audiometric reference level. Standard threshold shift under the Noise Regulations 1989 means an average shift of more than 10 dB at frequencies of 2000, 3000 and 4000 Hz relative to the baseline audiogram in either ear (Factories and Machinery Act 1967, 2014).

2.4 Hearing Conservation Program (HCP)

Hearing Conservation Program (HCP) can be defined as a formal planned and written program that is aimed at protecting workers who are exposed to significant occupational noise levels ; above 90 dB(A) from developing NIHL. This is particularly important as NIHL is largely preventable through the development and implementation of an effective HCP, whereby a set of coordinated measures are carried out systematically. Periodic audiometric testing allows for early detection of hearing loss and prevents further hearing loss by enforcing preventive measures (Hong, Kerr, Poling, & Dhar, 2013).

An effective HCP consists of several components which help employers to identify, assess, monitor and control noise hazard in a comprehensive and integrated way. A well-documented HCP generally consists of the following elements (Factories and Machinery Act 1967, 2014; Occupational Safety and Health Administration, 2002):

i. Safety and health policy
ii. Noise control
iii. Noise monitoring
iv. Provision of hearing protection
v. Training and education programme
vi. Audiometry testing
vii. Record keeping

2.4.1 Research background on Hearing Conservation Program around the world and Malaysia

Based on the Cochrane Systematic Review on Interventions to prevent occupational noise-induced hearing loss by Verbeek at al., proper use of hearing protection devices in a well-implemented hearing conservation program (HCP) was associated with less hearing loss. This review also included three studies that compared a less well-implemented hearing conservation program to a well implemented hearing conservation program and found that the occurrence of standard threshold shift (STS) is lower in the latter. This shows that a well implemented HCP is effective in prevention of hearing loss (Jh, Kateman, Tc, Wa, & Mischke, 2012).

Another clustered randomized trial by Berg et al. that looked into short term outcomes of implementation of a HCP for agricultural students showed that students receiving the HCP reported an increase in use of hearing protection devices. However, it did not find any significant reduction in levels of NIHL but this can be attributed to the short study duration (three years) which may not be sufficient to evaluate this HCP and a long term follow-up was subsequently planned (Berg et al., 2009).

Verbeek et al. also published another article that reviewed evidence from systematic reviews on occupational safety and health (OSH) interventions in low and middle-income countries. The findings were that environmental and behavioral interventions proved to be effective interventions in preventing occupational NIHL. The environmental interventions included legislation and behavioral interventions included training and education and also reported that HCPs are effective in prevention of NIHL in the long term (Verbeek & Ivanov, 2013).

Another retrospective cross-sectional study by Fonseca *et al.* reported that the implemented HCP was effective in preventing further worsening of hearing loss among the workers of the furniture company that have been diagnosed with NIHL. This shows that the progression of hearing loss was prevented effectively with the program in place, thus they recommended the use of a proper HCP in job sectors that are exposed to noise (Fonseca, Marques, Panegalli, Gonçalves, & Souza, 2014).

According to Mohammadi in a survey carried out to evaluate the effect of existing HCPs on workers' health and safety in 65 metal fabrication industries in Tennessee, USA, the majority of the metal fabrication industry workers were exposed to noise hazard and HCPs were required to protect the health and safety of the workers. Besides that, periodic audiometric testing and scheduled noise exposure measurements are essential for an effective HCP. This study also emphasized the need for a training and education program for workers to prevent hearing loss (Mohammadi, 2008).

Hearing conservation programs is a form of health promotion program. Hence it needs to be evaluated to ensure the purpose of the program is achieved which is prevention of hearing loss (Griest, 2008). A number of studies measured changes in hearing threshold levels among workers pre- and post-intervention (hearing conservation program) to evaluate the effectiveness of the hearing conservation program since this method provides an objective measure (Pell, 1972, 1973). Since noise-induced hearing loss (NIHL) is a slow progressing disease and develops after three to five years of exposure to excessive noise, it is impossible to use NIHL as an outcome when evaluating the effectiveness of a hearing conservation program. Hence, the use of standard threshold shift as an outcome has widely been used to determine the effectiveness of a hearing conservation program. This is particularly due to the fact that a threshold shift can occur after a short period of exposure to excessive noise but caution must be taken to differentiate temporary from permanent threshold shifts. The reason for this is temporary threshold shift is due to auditory fatigue and is reversible. Some studies have also recommended a threshold shift of 15 dB or more at any frequency in either ear to be used as a measure of outcome in evaluation (Royster, Lilley, & Thomas, 1980). The method used to evaluate a hearing conservation program also largely depends upon available data and resources. For instance availability of an audiometric database of workers hearing threshold would be make evaluation of effectiveness a hearing conservation program more feasible.

In Malaysia, there lacks research on the effectiveness of HCP in preventing hearing loss. A cross-sectional study done among industries in a central state found that most industries failed to have an effective HCP because they lacked control and monitoring of occupational noise exposure as well as training and education regarding noise hazard to the workers. However, the prevalence of hearing loss was found to be higher in industries that fully complied with HCP and this is due to the proper noise monitoring and periodic audiometric testing that was carried out which allows for better detection of hearing loss among workers (Nor Saleha & Noor Hassim, 2006).

2.4.2 Benefits of Hearing Conservation Program (HCP)

An effective HCP can prove beneficial to both employer and employee but the primary or main benefit is preventing hearing loss among employees. However, given the implications of hearing loss on an individual such as reduction in quality of life and difficulty to communicate with others, HCP is of major importance. Communication is a vital part of life and in many job sectors communication is needed for a worker to function optimally and prevent workplace injuries. In many job sectors as well, adequate hearing is needed to convey and receive instructions, detect machinery sounds and warning signals. At an interpersonal level, adequate hearing is needed to communicate with family members and friends to fulfill the pleasures in life. Besides that it is also needed for certain hobbies that may play a role in relaxation and stress reduction such as listening to music, playing musical instruments and other recreational purposes. The HCP can also act as a health screening tool because it includes periodic audiometric testing that allows for detection of non-occupational hearing losses as well as other treatable ear diseases (Mcneely, n.d.).

The employers will also benefit from an effective HCP in terms of reduced compensation claims from workers as a result of reduced incidence of occupational hearing loss. A study done in metal fabrication industries revealed that absence of a HCP results in additional hearing disability claims among workers where by 9% of the metal fabrication industries in this study that did not have any hearing conservation program also showed 9% of hearing disability claims. This shows a positive relationship between an effective HCP and compensation claims for hearing loss (Mohammadi, 2008). In terms of productivity, a healthy worker is definitely more productive and will increase revenue for management. The other ill effects of excessive noise on health such as stress, fatigue and depression will also be prevented and this in turn will account for reduced absenteeism and medical expenses for the employer. Besides that, reduction in accident rates due to better communication between workers without hearing loss is also a good reflection of an industry or management in terms of commitment towards the health and safety of their workers (Franks, Stephenson, & Merry, 1996).

An effective HCP is also one aspect of an overall employer's safety and health policy and shows the employers commitment towards their workers and this is important because it improves employer-employee relationship and reduces worker attrition rates. The need for a HCP is also a legal requirement in workplaces with a noise exposure level of more than 90 dB (A) and employers can achieve compliance to OSHA as well as other governmental regulations (Mcneely, n.d.).

2.4.3 Elements of a Hearing Conservation Program (HCP)

There are many guidelines on developing an effective HCP available internationally and locally. However, for the given program to be effective, all elements of the program must be given equal attention and none must be neglected. Proper coordination between employers and employees play a vital role as employees can ensure a successful HCP. Although they may not be involved in the development or funding of the policy/program but they are involved in the implementation phase at the field or operational level. Employees must have that sense of internalization in order to adapt and practice what is outlined in the program. A comprehensive HCP according to National Institute of Occupational Safety and Health (NIOSH) USA in their "Guide to Preventing Occupational Hearing Loss" consists of seven elements (Franks et al., 1996):

- Monitoring noise hazards: To determine the noise exposure level of workers at the workplace using either a sound level meter (SLM) or a noise dosimeter (personal monitoring).
- Engineering and administrative controls: Taking appropriate measures to control the noise hazard that has been identified.
- Audiometric evaluation: Pre-employment and periodic audiometric testing of the workers hearing is required depending on the baseline audiogram.
- Personal hearing protection devices: Proper and appropriate usage of hearing protection devices by workers is practiced along with training.

- Education and motivation: Employers and employees must be educated regarding the causes of hearing loss and the ill effects of excessive noise on health. They must also be informed regarding methods to prevent hearing loss and to keep them motivated in practicing those steps and not force it upon them.
- Record keeping: Systematic and safe keeping of all audiometric records, reports of hearing protection use and analysis of hazardous exposure measurements.
- Program evaluation: Periodic evaluation of the program is needed to ensure that the program is achieving its objective or goals which is to prevent hearing loss among workers. This can be done via two approaches which is to assess the completeness and quality of the program elements and evaluate audiometric data.

In the guide proposed by the US Department of Labor, an eighth element is added, which is program audit. Technically most programs incorporate this step although it is often not spelled out in the program elements. The hearing conservation program audit is to be conducted at the beginning of the program and it involves assessing available resources, required assets and expected outcome of the HCP (Franks et al., 1996).

In Malaysia, the Noise Regulation 1989 under the Factory and Machinery Act 1967, stipulates the requirement for factories with noise hazard. This regulation requires a HCP to be implemented in workplaces with excessive noise that includes the following seven elements (Federal Subsidiary Legislation, 1989):

- Safety and health policy
- Noise exposure monitoring
- Noise control measures
- Provision of hearing protection devices (HPD)
- Audiometric tests and evaluation

- Training and education program for workers
- Systematic record keeping of audiometric tests, training records, maintenance records and exposure monitoring records.

The North Carolina Department of Labour also mentioned factors that may lead to an ineffective HCP in their guideline titled "A Guide to Developing and Maintaining an Effective Hearing Conservation Program" and it is important for program implementers to be understand these factors prior to implementation of the HCP in order to avoid similar mistakes. Some of the causes of an ineffective HCP mentioned in this guide are (Mcneely, n.d.):

- Lack of communication and coordination between the top management level and operational level.
- Lack of evidence informed decisions.
- Absence of adequate training for workers in particular proper usage of HPDs.
- Lack of analysis on audiometric results to evaluate the effectiveness of the HCP and not informing workers on their audiometric test results.

2.5 Systematic review

A systematic review of recent evidence on effective strategies to prevent noise-induced hearing loss (NIHL) was conducted as part of the first phase of this study which is development of a comprehensive Hearing Conservation Program (HCP). This systematic review was registered in the PROSPERO database of reviews with the registration number CRD42017064644 and is made available at https://www.crd.york.ac.uk/PROSPERO. This section presents the key strategies identified from scientific literature that were later incorporated into the program.

2.5.1 Objective

The purpose of this systematic review is to review the evidence for effective workplace interventions to prevent NIHL among adult workers exposed to hazardous noise at the workplace which can be used in the development of future noise prevention and mitigation strategies including an effective hearing conservation program.

2.5.2 Method

A step-by-step approach was undertaken to ensure transparency and rigour in this systematic review process. The method for conducting this systematic review involves five steps mainly:

i. Framing the review question
ii. Setting the search parameters
iii. Data extraction
iv. Data synthesis
v. Interpreting the findings

2.5.2.1 Review question

The review question was framed based on the PICO elements which includes:

i. P (Population)

Adult workers exposed to and/or workplaces with high noise levels (i.e. more than 80 dB (A) as a time-weighted average (TWA) over a period of an entire work shift or working day or part of the work shift).

ii. I (Intervention)

All interventions aimed at preventing noise-induced hearing loss (NIHL) in the workplace which may consist of one or more of the following elements:

- Engineering controls: Performing noise exposure monitoring and reducing or eliminating the noise from the source based on exposure monitoring results
- Administrative controls: Training and education program, organizational or management policies and supervision
- Hearing surveillance for workers including audiometric testing
- Use of personal protective equipment or personal noise protection devices

iii. C (Comparison)

No intervention

iv. O (Outcomes)

Noise exposure levels, hearing threshold levels (audiometry testing) and workers perception and acceptability of intervention.

2.5.2.2 Inclusion and exclusion criteria

The following inclusion criteria were used for selection of studies in this review:

i. Population studied are adult workers aged 19 years and above whom are exposed to noise levels more than 80 dB (A) as a time-weighted average (TWA)
ii. Only English language publications were selected
iii. Scientific literature published within the past 10 years from 1/01/2007 to 31/12/2016.
iv. No limitation of setting has been set, thus studies from all regions in the world were included in this review.

Studies were excluded if it had any of the following criteria:

i. Animal studies were not selected.

ii. Qualitative study designs

iii. Editorials, opinion pieces, commentaries, letters and conference proceedings.

2.5.2.3 Search strategy

A systematic evidence-based search of scientific literature dated between 1st January 2007 to 31st December 2016 was conducted in PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL) and Scopus while reviewing relevant textbooks and references from the studies that were published within the past 10 years from 1/01/2007 to 31/12/2016. These databases were selected as they are widely used among allied health professionals and easily accessible. PubMed was selected as it is easily accessible and covers a wide range of Health/Medical subjects. CINAHL database was included because it is the most widely-used and respected research tools for nurses, students and allied health professionals around the globe. Scopus was included for its extensive peer-reviewed literature and scientific journals.

In developing the search strategy for this review, three concepts were identified, in concordance with the PICO (population, intervention, comparison and outcome) statement. The concept of "Noise-induced Hearing Loss" was taken as the primary concept. Next, the concept of "Occupation" was applied to assess the volume of literature related to noise-induced hearing loss and occupation. The third concept of "Strategies to prevent noise-induced hearing loss (NIHL)" was applied to assess the volume of literature related to NIHL and occupation and strategies to prevent it. Based on the study by Verbeek et al. (2005), a search strategy was developed using keywords and search strings found to have sensitivity and specificity in locating occupational health interventions studies on reduction of noise exposure and hearing loss prevention, and additional concepts of specific interest to this literature review (Verbeek et al., 2005). The keywords related to three relevant concepts that were used in the literature search includes:

i. Concept one: noise induced hearing loss, noise exposure, hearing loss
ii. Concept two: work, occupation, job
iii. Concept three: prevention, reduction, isolation, management program, engineering controls, administrative controls, personal hearing protective equipment, hearing protection device, hearing conservation, hearing surveillance, program, strategy, intervention, effect, control, evaluation

In the databases, a combination of indexed keywords and free text words were used to search and "OR" was used to connect keywords within concepts while "AND" was used to merge different concepts. To minimize irrelevant results, the terms were searched in title fields only. The search was completed in June 2017 and is limited to English language scientific peer-reviewed literature published during the period of the last 10 years up to 31st December 2016.

2.5.2.4 Data extraction and quality assessment

Authors independently reviewed the titles and abstracts and excluded those not deemed relevant. Full articles were retrieved for articles that met the inclusion criteria of this review. Discrepancies in search results were resolved by discussion among authors. For each study included, data was extracted and risk of bias was assessed by the authors. Data was extracted using a standard form (see Appendix A) that included information on study characteristics (study design, randomization methods), setting, sample population, interventions and outcomes.

The quality of evidence extracted on strategies to prevent noise-induced hearing loss (NIHL) was evaluated using a body of evidence matrix as outlined by the National Health and Medical Research Council (NHMRC) 2009 on levels of evidence and grades for recommendations for developer of guidelines (Australian Government, 2009). This tool allows for appraisal of the internal validity of the studies including consistency and potential impact of the intervention. Apart from that, it helps with identifying external factors that may influence the effectiveness of the proposed recommendation in practice, in terms of generalisability to the target population and applicability to the Malaysian health care system. Details of the quality assessment process are explained further in section 3.1.14.

2.5.3 Results

2.5.3.1 Summary of included articles

The initial search yielded 203 articles from three electronics database (CINAHL, PubMed and Scopus) search. The screening of references for eligibility resulted in 184 full-text articles after 19 articles were removed due to duplicates. Following the screening of the titles, 75 articles were identified for further investigation out of which 46 articles were excluded after screening of abstracts for not having any one of the three outcomes of interest (noise exposure, noise-induced hearing loss and perception and acceptability of intervention by worker/employee) or are not the desired study design. As at the final point, 20 out of the 29 remaining articles were excluded based on screening of the full text and critical reading. Therefore, in this systematic review, we use the results of nine studies on the effective strategies to prevent noise-induced hearing loss. The flowchart in Figure 2.1 shows the details of the search and reasons for an articles' exclusion and Table 2.1 provides the list of articles included in this review.

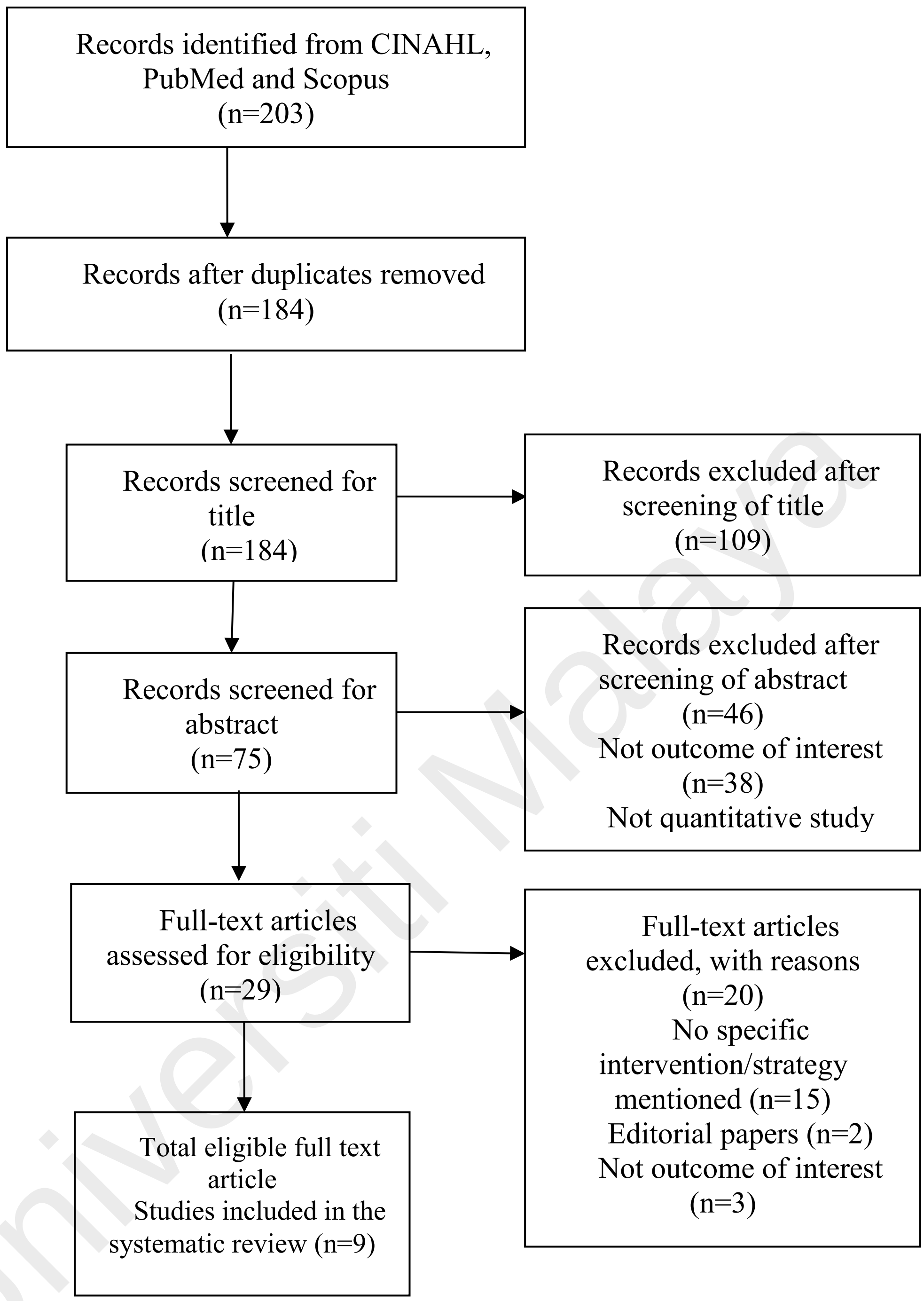


Figure 2.1: PRISMA Flowchart

Table 2.1: Articles included in the systematic review

Author(s)	Year	Publications specification
Rocha, C.H., Santos, L.H.D., Moreira, R.R., Neves-Lobo, I.F. and Samelli, A.G.,	2011	Effectiveness verification of an educational program about hearing protection for noise-exposed workers. *Jornal da Sociedade Brasileira de Fonoaudiologia*, *23*(1), 38-43.
McCullagh, M.C.	2011	Effects of a low intensity intervention to increase hearing protector use among noise-exposed workers. *American journal of industrial medicine*, *54*(3), 210-215.
Davies, H., Marion, S. and Teschke, K.	2008	The impact of hearing conservation programs on incidence of noise-Induced hearing loss in Canadian workers. *American journal of industrial medicine*, *51*(12), 923-931.
Riga, M., Korres, G., Balatsouras, D. and Korres, S.	2010	Screening protocols for the prevention of occupational noise-induced hearing loss: the role of conventional and extended high frequency audiometry may vary according to the years of employment. *Medical Science Monitor*, *16*(7), CR352-CR356.
Rabinowitz, P.M., Galusha, D., Kirsche, S.R., Cullen, M.R., Slade, M.D. and Dixon-Ernst, C.	2011	Effect of daily noise exposure monitoring on annual rates of hearing loss in industrial workers. *Occupational and environmental medicine*, 414-418.
Takahashi, K., Kawanami, S., Inoue, J. and Horie, S.	2011	Improvements in Sound Attenuation Performance with Earplugs Following Checklist-based Self-practice. *Journal of* University of Occupational and Environmental Health, *33*(4), 271-282.
Seixas, N.S., Neitzel, R., Stover, B., Sheppard, L., Daniell, B., Edelson, J. and Meischke, H.	2011	A multi-component intervention to promote hearing protector use among construction workers. *International journal of audiology*, *50*(1), S46-S56.
McTague, M.F., Galusha, D., Dixon-Ernst, C., Kirsche, S.R., Slade, M.D., Cullen, M.R. and Rabinowitz, P.M.	2013	Impact of daily noise exposure monitoring on occupational noise exposures in manufacturing workers. *International journal of audiology*, *52*(1), S3-S8.
Williams, W., Brumby, S., Calvano, A., Hatherell, T., Mason, H., Mercer-Grant, C. and Hogan, A.	2015	Farmers' work-day noise exposure. *Australian Journal of Rural Health*, *23*(2), 67-73.

2.5.3.2 Identification of three key noise-induced hearing loss (NIHL) prevention strategies

The range of programs and interventions identified to prevent NIHL was heterogeneous in study design, outcome measures, geographical locations and types of industry thus precluding any statistical meta-analysis. Thematic synthesis of the intervention studies identified the following three key strategies for noise-induced hearing loss (NIHL) prevention: multifactorial interventions, leadership and one-off training sessions (Figure 2.2).

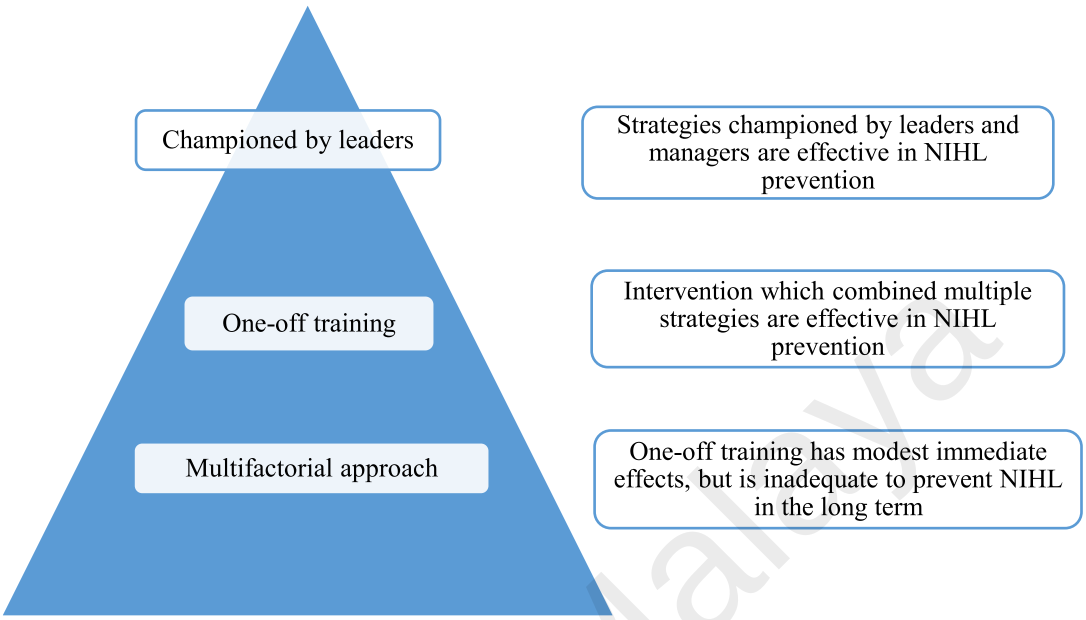


Figure 2.2: Three key strategies in noise-induced hearing loss (NIHL) prevention.

2.5.3.3 Study characteristics

All nine of the included studies were quantitative methodology in nature. Two of the studies were one off training (McCullagh, 2011; Neves-Lobo, & Samelli, 2011; Rocha, Santos, Moreira), five were multifactorial interventions (Davies, Marion, & Teschke, 2008; Rabinowitz et al., 2011a; Riga, Korres, Balatsouras, & Korres, 2010; Seixas et al., 2011; Takahashi, Kawanami, Inoue, & Horie, 2011) and two were championed by leaders (McTague et al., 2013; Williams et al., 2015). Table 2.2 provides information on the design methodologies, participant characteristics, outcome measures and results of the studies included in this systematic review. An overview of the empirical evidence and methodological quality of the effectiveness of the studies will follow in the discussion section.

In terms of study design, two studies applied a controlled before-after (CBA) study design with Rabinowitz et al. (2010) using interrupted time series (ITS) for additional data analysis (Davies et al., 2008; Rabinowitz et al., 2011a). Another two studies involved a randomized controlled trial (RCT) design with Seixas et al. (2011) applying both cluster and individual randomization (Rocha et al., 2011; Seixas et al., 2011). Three studies applied a one group pre and post-test design without a control group (McCullagh, 2011; McTague et al., 2013; Takahashi et al., 2011). The remaining studies, Williams et al. (2015) included a cross sectional design and Riga et al. (2010), a prospective cohort study comparing Extended High-Frequency (EHF) versus Conventional Audiometry. The smallest sample size among the nine studies included in this review is ten university medical students (Takahashi et al., 2011) whereas the largest sample size is 22,376 lumber mill workers (Davies et al., 2008). The identified studies show various industries where noise-induced hearing loss (NIHL) is being addressed, with research in a wide range of sectors including manufacturing, lumber mill, farm, food processing, hospital, construction, smelting industry and university students.

Table 2.2: Characteristics of included studies

Author/ Year	Design	Participants	Interventions	Outcomes	Notes
Williams et al., 2015	Cross sectional	Farmers; n = 85; Australia Farmers for noise exposure monitoring (n = 51) Respondents for the noise audit report (n = 85)	Championed by leaders: Noise exposure assessment and noise audit report booklet	Effectiveness/relevance of the noise audit report assessed using a short questionnaire (seven questions).	Comparability: Age: No data available
Mctague et al., 2013	One group pre and post test	Workers from aluminium smelter and turbine component manufacturing factories; n = 127; USA	Championed by leaders: Voluntary use of daily noise exposure monitoring device consisting of a dosimeter equipped with visual warning signals to alert workers when exposed to excessive noise.	Daily noise exposure levels and change in noise exposure over time in decibels (dB)	Comparability: No control group, blinding and randomization
Rocha et al., 2011	RCT	Hospital staff; n = 78; Brazil	One-off training: Educational training in the form of graphic material on noise-induced hearing loss (NIHL) including use and care of hearing protectors	Knowledge, attitude and practice towards noise (comparison before and after intervention) measured using a scoring questionnaire.	Comparability: Age: No data available Job sector of participants and follow up period not mentioned

‘Table 2.2, continued’

Author/ Year	Design	Participants	Interventions	Outcomes	Notes
McCullagh et al., 2011	One group pre and post-test	Farmers; n = 32; USA	One-off training: Model-based mailed intervention consisting of hearing protectors and instructions of use	Use of hearing protection devices.	Comparability: Age: No data available Short-term follow-up: 2-3 months
Seixas et al., 2011	Both cluster and individually randomized RCT	Construction workers from various trades; n = 176; USA	Multifactorial interventions: Many comparisons possible we choose to compare two interventions considered to be most relevant for practice. Intervention 1: baseline training plus noise ‘tool box’ onsite training (n = 44) Intervention 2: baseline training plus noise ‘tool box’ onsite training plus personal noise level indicator (n = 41)Control: baseline training (n = 46)	Noise level measured as Laeq at two and four months follow-up	First baseline training, then cluster-randomized to tool-box; then individuals were randomised to noise level indicators or no indicators

'Table 2.2, continued'

Author/ Year	Design	Participants	Interventions	Outcomes	Notes
Rabinowitz et al., 2011	CBA/ ITS (authors provided additional data for ITS analysis)	Various workers of an aluminium smelter; n = 312; USA	Multifactorial interventions: Daily noise exposure monitoring and regular feedback on exposure from supervisors. Control: on-going hearing conservation program (regulation mandated hearing tests, noise measurements, training)	Median TWA ambient noise exposure; median and range of noise exposure inside hearing protection (intervention group); high frequency hearing threshold levels (2, 3, 4 kHz); annual rate of hearing loss (dB/year)	Comparability : (matched on age, gender and hearing) Age: similar age (within 5 years); Intervention mean 48.7 years; control mean 48.6 years Hearing: controls matched (C1) and highly matched (C2): C1: baseline hearing = similar high frequency hearing threshold levels (binaural average of 2, 3 and 4 kHz) (within 5 dB) (n = I 78/C 234) C2: baseline hearing and initial rate of hearing loss during pre-intervention period (n = I 46/C 138)
Takahashi et al., 2011	One group pre and post test	Medical students from a university school of medicine; n = 10; Japan	Multifactorial interventions: Individual training on earplug use and checklist based self-practice.	Changes in sound attenuation of earplugs and standard deviation pre and post intervention.	Comparability: Age: No data available Small sample size with participants being highly educated and well versed with dangers of noise

'Table 2.2, continued'

Author/ Year	Design	Participants	Interventions	Outcomes	Notes
Riga et al., 2010	Prospective cohort study	Workers in food processing plant; n = 151; Greece	Multifactorial interventions: Noise exposure assessment and extended high frequency (EHF) audiometry	Shift or changes in hearing threshold.	Comparability: All groups matched for exposure to tobacco smoke
Davies et al., 2008	CBA	Lumber mill workers; n = 22 376; Canada, British Columbia Intervention: Hearing conservation programme; n = 16 347 Control: those exposed to less than 80 dB-years plus those at their first hearing test following baseline; n = 6002 estimated from the number of person-years of 41 357 with 6.8-year follow-up	Multifactorial interventions: Hearing conservation program (HCP)	Standard threshold shift (STS): 10 dB or greater at 2, 3 or 4 kHz in the better ear.	Comparbility : Proportional hazards model to adjust for age and hearing ability at baseline

Abbreviations: CBA = Controlled before-after study; ITS = Interrupted time-series; RCT = randomized controlled trial

2.5.4 Discussion

This section provides an overview of the evidence from the systematic evidence based reviews of various occupational health interventions and its effectiveness in the prevention of noise induced hearing loss (NIHL). Interventions that showed positive impacts on NIHL prevention range from a large scale multifactorial approach that combines different interventions to one-off workplace training and education sessions. The effective strategies or interventions identified in this review have been categorised into three main categories as mentioned previously: championed by leaders, one-off training and multifactorial approach.

Strategy 1: Championed by leaders

Two studies highlighted the key role played by external leadership and workplace management in the effective implementation of changes (McTague et al., 2013; Williams et al., 2015). The impact of the interventions in both studies were moderate to high, as improvements were demonstrated in outcomes measured mainly through noise exposure levels as well as perceptions towards noise, number of noise control measures in place, and non-statistical descriptions of improved noise exposure. Studies have not been performed which demonstrate the effectiveness of this approach in terms of reduction in NIHL claims or improved audiometry. These studies were performed in different sectors: farming and the manufacturing industry.

The study by Williams et al. (2015), showed that feedback from superiors using a noise audit report consisting of the following information: findings of noise exposure assessment with explanation and methods to reduce exposure to excessive noise is effective in raising awareness among farmers and noise exposure management. The driving force behind this survey and the resultant intervention was part of a larger

National Health & Medical Research Council project, 'Sustainable Farm Families', a program coordinated by the National Centre for Farmer Health, Deakin University which is intended to improve the health, wellbeing and safety of farm families. The participants of this study were from a convenience sample drawn from the 'Shhh-hearing in a farming environment' project which is part of the Sustainable Farm Families (SFF) Program, 51 farmers (14 female and 37 male workers) for exposure monitoring and 85 respondents for the noise audit report participated voluntarily. This may result in sampling bias affecting the generalizability (external validity) across other job sectors as the participants only included farmers who have previously received training on proper use of hearing protectors from the 'Shhh-hearing in a farming environment' project. Hence they are more aware of the dangers of excessive noise and more likely to take preventive measures such as proper use of hearing protectors.

This study aims to understand the extent of farmers' exposure to hazardous noise, and trial and test the ability of an on-farm noise audit report in improving awareness and preventative action towards farm-based noise hazards. The feedback given by supervisors in the form of a noise audit report includes noise exposure assessment of daily activities through dosimetry; measurements of noisy tasks and machinery; supply and interpretation of a noise audit report. In addition to the noise report audit, participants were furnished with a personalised noise booklet to meet individual farm needs which outline, noise levels, the acceptable exposure time, an explanation of their meaning/implication(s) and brief suggestions about how to reduce noise exposure. The results clearly show that men and women have similar risk to exposures. The average noise exposure was 85.3 dB for an 8 hour time-weighted average (TWA) which is above the recommended Australian exposure standard of 85 dB. Therefore, of those measured, 51%, and by extrapolation 163,000 Australian agricultural workers, have noise exposure levels greater than the recommended standard putting them at risk from hazardous noise. Men and women are both equally exposed. The intervention proved effective in enhancing knowledge and awareness towards hearing among the farming communities which is crucial in overcoming hesitance to undertake preventive actions towards excessive noise exposure. This evidence is supported by the Health Belief Model (HBM) that attempts to predict health behaviours where information provided by the leaders/supervisors improves farmers' knowledge with regards to perceived susceptibility and severity of damaging noise as well as perceived benefits of applying preventive behaviour at work (Rosenstock, 1974). Given this adequate information, they will promote awareness and a positive safety climate within the organization including reinforcing the need for hearing protection and ultimately improving workplace health and safety. Changing health behaviours associated with hearing loss prevention is a challenging task and requires health communication at all levels (intrapersonal, interpersonal, organizational, community and public/mass) to develop an effective intervention to prevent hearing loss among workers (Corcoran, 2007). The noise audit report and booklet in this study serves as a method of health communication in conveying relevant information to the farmers that translates into preventive behaviour with respect to hearing loss.

The intervention study by Mctague et al. (2013) assessed the effectiveness of voluntary use of a daily noise exposure monitoring device with visual warning signals to alert workers when exposed to excessive noise. The workers also received a printed copy of monthly summaries of their exposure data individually via mail. This study was part of a research collaboration initiative between the administrators of the company Alcoa Inc. and academic institutions (Yale University School of Medicine and Stanford University School of Medicine) as part of the their hearing conservation program. Volunteers were fitted with a device allowing them to monitor noise exposure under their hearing protection on a daily basis. The trends in noise exposure for individuals who completed at least six months of the intervention were analysed. The results highlighted that among volunteers downloading regularly, the percentage of daily exposure in excess of the OSHA action level (85 dB) decreased from 14% to 8%, while the percentage of daily exposure in excess of 90 dB decreased from 4% to less than 2%. Since the noise overexposure appeared to be driven by a small number of individuals working near a loud noise source, further multivariate analysis was performed to determine if individual factors played a role in individual noise reduction over the first six months of using the monitoring device and results show neither age, gender, HPD type, baseline hearing, nor baseline noise exposure level (average exposure level in first month of downloading) were significantly associated with the rate of decrease in noise overexposure that individuals achieved. The initial results from this longitudinal study indicate that providing workers regular feedback on their daily noise exposure monitoring proved to be feasible and effective in reducing noise exposures by raising awareness regarding noise exposure levels and subsequently promoting steps to control noise exposure: avoidance of noise sources or reducing exposure time, informing supervisors of excessive noise source and proper use of hearing protectors. Since the recruitment occurred at three manufacturing facilities of the company with different production process (two aluminium smelter and one turbine component) with some sites having a low number of participants due to a significant number of layoffs because of the economic downturn, this resulted in different types of noise exposure between the smelter and turbine component factory. The lack of blinding and randomization with no control group may affect the internal validity of this study. The results of participant adherence shed light on the challenges and possibilities of worksite interventions for health and safety.

Body of evidence summary: Championed by leaders

The evidence from the quantitative literature identified in review is consistent across the studies supporting the importance of leadership especially within an organization in effective occupational NIHL prevention. However, the quality of evidence supporting it is weak due to both studies having a cross sectional and one group pre and post-test design as well as high risk of bias identified. The impact of leadership in preventing NIHL has been demonstrated in outcomes such as reduction in noise exposure levels in the study by Mctague et al. (2013) but the other study only reported qualitative feedback from the employees. Although both studies were conducted in different job sectors, the population studied are almost similar in terms of socioeconomic status and the recommendations should be applied with caution. The body of evidence summary for this strategy is shown in Figure 2.3.

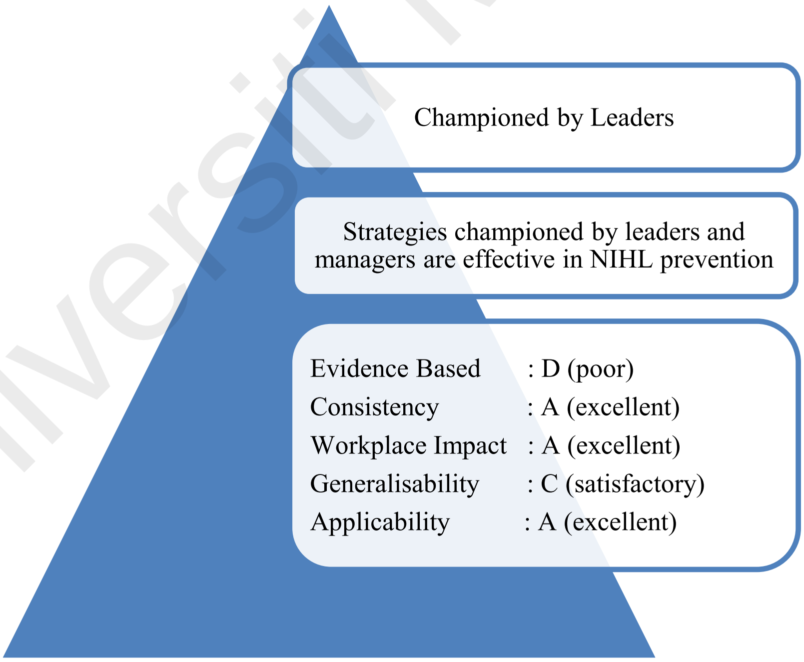


Figure 2.3: Body of evidence summary for championed by leaders

Strategy 2: One-off training

Two studies evaluated the effectiveness of a one-off training intervention in preventing noise-induced hearing loss (NIHL) by increasing hearing protector use among employees exposed to excessive noise. McCullagh et al. (2011) emphasized the importance of hearing protection devices whereas the study by Rocha et al. (2011) verified the effectiveness of an educational program in the form of training to raise awareness on hearing protection among workers exposed to occupational noise. In both studies, one-off training produced substantial impact in raising awareness as well as increased use of hearing protectors among employees. These studies were performed in two very diverse job sectors, farming and healthcare services but the sample population is not clearly defined in the latter especially in terms of job title and job description of workers involved the study. In the study by McCullagh (2011) study participants received an assortment of hearing protectors via mail with manufacturer instructions for use whereas Rocha et al. (2011) tested an educational training program consisting of graphic material and illustrative figures with information on importance of hearing, noise effects on health, NIHL prevention, importance of use information on the correct manner of placing the hearing protector, conservation and cleaning of protectors and noise levels in the work environment and noise attenuation provided by hearing protectors. The main outcome from the former study showed a significant overall increase of 44% in self-reported use of hearing protectors. This suggests a moderate to high impact of the mail-based intervention of hearing protectors on workers and was clearly well accepted by the farm operators. This mailed intervention form of training with instructions makes hearing protectors easily available to workers hence increasing use and improves their perceived self-efficacy with regards to safety and health. Unfortunately, factors influencing acceptance and usage of the hearing protectors are not completely understood. The health promotion model by Pender (2006) suggests that health promotion behaviour is influenced by attitudes, beliefs, habits, behaviour history and individual factors (such as age and gender) (Pender, 2011).

On the other hand, Rocha et al. (2011) reported up to 13% improvement in mean accuracy per individual and 23% improvement in mean accuracy per question in the research group as compared to the control group after receiving the educational training. This significant increase reflects improvement in knowledge regarding workplace noise levels as well as use and care of hearing protectors among participants whom received the educational training proving the effectiveness of this intervention since a fairly large impact is seen. These findings are supported by Hamblin (1974) in which training results in a chain reaction which triggers learning to increase knowledge and awareness that leads to a change in behaviour and practice at the individual and organizational level. A similar flow is also proposed by Kirkpatrick's model of training evaluation criteria which includes four levels that are positively intercorrelated mainly, reactions, learning, behaviour and results. According to Kirkpatrick (1989), the four levels or categories serve as measures of effectiveness of training outcomes where trainees' attitude towards training gives rise to learning that results in trainees applying new principles or techniques learnt. This will result in the desired goals of the organization such as lowered cost for management, reduction of turnover and absenteeism of workers as well as increase in production quality and quantity (George & Elizabeth, 1989). Training related to safety also serves as a method for hazard communication between employers and employees and improves safety knowledge and performance while raising awareness among workers exposed to noise hazards (Burke et al., 2011).

Both studies reported effectiveness of the intervention at different time lines with McCullagh (2011) assessing immediate effects (within one hour post-training), whereas

Rocha et al. (2011) described medium-term effects (2-3 months post-training). Although both studies showed significant improvement in safety knowledge and increased use of hearing protectors among workers post-training, the long-term outcomes of both training programs are not studied.

In summary, the present study reinforces past research that training is impactful in changing individual as well as organizational attitude and behaviour towards health and safety. The findings of present studies also emphasize the need for educational training to improve the awareness of workers about the damage caused by noise, the use and efficiency of protectors for hearing loss prevention, as well as care of such devices, as a way to assist in the prevention of noise-induced hearing loss. Furthermore, the findings underscore the importance of evaluation of training to identify strengths and weaknesses of the training program and its suitability for a given work environment.

Body of evidence summary: One off training

Although findings from both studies were consistent with other studies in which training was a frequently evaluated strategy in prevention of noise-induced hearing loss (NIHL), a high risk of bias must be cautioned since level of evidence is weak with only one study using a no-intervention control group for comparison. In both studies, the one-off training program showed a very large impact among the workers with significant improvement in main outcomes such as safety knowledge and increased use of hearing protectors, however the use of hearing protectors was self-reported and long-term effects were not studied. This may affect the internal validity of this outcome measure, particularly when compared with more objective outcomes measures (e.g. observed hearing protector use and hearing protector attenuation). Study populations differed between both studies with Rocha et al. (2011) not clearly defining the job title or role of the participants except that they are staff at a hospital. This is vital as hospital staff are made up of professional and non-professionals that may affect the effectiveness of the training due to varying levels of education, hence the findings from these studies must be applied with caution. The body of evidence summary for this strategy is shown in Figure 2.4.

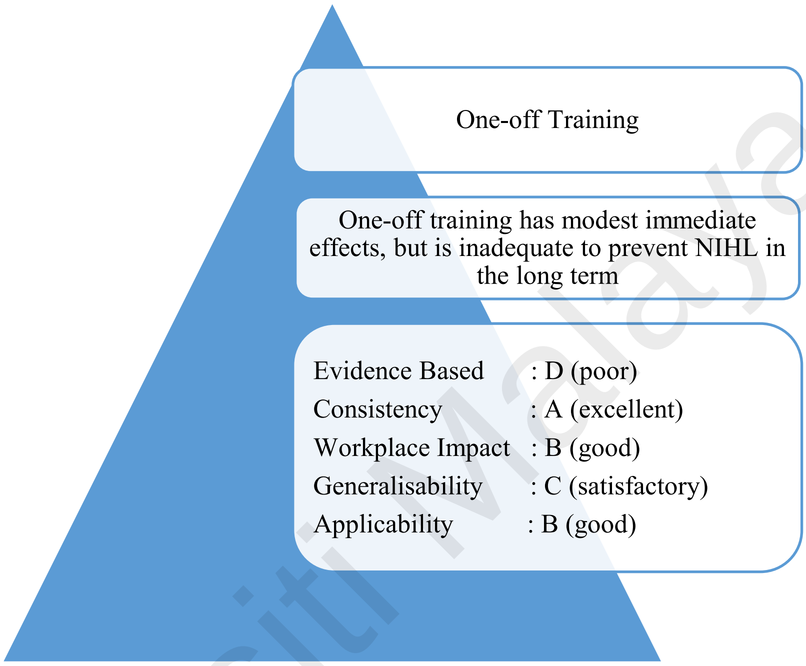


Figure 2.4: Body of evidence summary for one-off training

Strategy 3: Multifactorial interventions

Five studies evaluated the effectiveness of a combination of strategies in preventing noise-induced hearing loss (NIHL). Only one study by Davies et al. (2008), evaluated the effectiveness of a hearing conservation program or hearing loss prevention program however the details of each strategy in this hearing conservation program is not defined clearly. Although it was mentioned that the local legal requirements where the study took place (Canada), required employers to implement a hearing conservation program that incorporates seven elements, mainly noise exposure monitoring, implementing engineering and administrative controls, audiometric evaluation, hearing protection, education, record keeping and program evaluation. The outcome measured to determine the effectiveness of the hearing conservation program in this study was a standard threshold shift (STS) that showed a 51% reduction in the risk of standard threshold shift (STS) to participants who were employed after the implementation of the hearing conservation program (Davies et al., 2008). However these findings were interpreted without comparison to a proper control group without a hearing conservation program as there were audiometric test done prior to the existence of the program. The remaining four studies implemented different combination of strategies in preventing noise-induced hearing loss (NIHL) but they did not qualify as a hearing conservation program. All five studies were conducted in various job sectors including manufacturing, construction and food processing as well as the education sector. The varying nature of the populations in the studies especially educational level makes direct comparison of the interventions to determine its effectiveness difficult. Takahashi et al. (2011) studied the effectiveness of an intervention made up of training and a checklist-based self-practice on the proper use of earplugs among university medical students. Although the outcome from this study showed significant improvement in sound attenuation of the students ranging from 7.7 dB to 11.7 dB in all frequencies, these findings must be interpreted with caution (Takahashi et al., 2011). A high risk of bias is anticipated due to the small sample size (ten medical university students) and high educational level of participants with prior knowledge regarding dangers of noise and preventive methods to preserve hearing. In Seixas et al. (2011), comparison was made between a varieties of combination of interventions made up of three main strategies: baseline training, follow-up toolbox training and personal noise level indicators. There was a significant increase in use of hearing protection devices by 12.1% two months after the intervention and 7.5% four months after the intervention when compared to pre-intervention with greatest increase shown in the group receiving a combination of all three strategies (baseline training, follow-up toolbox training, and personal noise level indicators), up to 24% at two months and four months post-intervention (Seixas et al., 2011). A similar pattern was observed in all groups with increase in use of hearing protection devices two months post-intervention but the mean use of hearing protection devices showed a reduction at four months post intervention in comparison to the former. Meanwhile the study by Riga et al. (2010), examined screening protocols for workers exposed to excessive noise taking into account the duration of employment of workers. The intervention included noise exposure assessment as well as comparing effectiveness between a conventional audiometry and an Extended High Frequency (EHF) audiometry in early detection of occupational noise-induced hearing loss (NIHL). This study examined the relationship between screening protocols taking into account duration of employment and found that Extended High Frequency (EHF) audiometry along with noise exposure assessment to be effective in early detection of noise-induced hearing loss (NIHL) especially during the first decade of employment where the higher frequencies (12500, 14000 and 16000Hz) were affected first (Riga et al., 2010). However, the effect of Extended High Frequency (EHF) audiometry in workers more than 55 years of age were not studied and this is important as most countries have increased employees' retirement age to more than 55 years old. Meanwhile in the study by Rabinowitz et al. (2010), an intervention combining daily noise exposure monitoring of workers and regular feedback on exposure levels showed a reduction of 0.5 dB/year in the average rate of hearing loss at high frequencies (2, 3 and 4 KHz). Although participants in the matched control group also showed a reduction in the average rate of hearing loss by 0.1 dB/year, it was fairly lower compared to the intervention group. A similar trend was observed during comparison of the difference between the pre-intervention and post-intervention rates of hearing loss for both intervention and control groups but the difference was not statistically significant (Rabinowitz et al., 2011a). This intervention is similar to the daily noise exposure monitoring device with visual warning signals by Mctague et al. (2013) but the additional component of risk communication via regular feedback from supervisors shows organizational commitment towards safety and health of workers and will further motivate them to practice safety culture at the workplace. Risk communication is important especially in enhancing knowledge, building employer-employee trust and credibility as well as encouraging appropriate attitudes, behaviours and beliefs. Similar findings were observed among construction workers that were given daily on-site verbal communication on level of safety and safety climate at the construction site (Kines et al., 2010). However, another study by Michael et al. (2006) reported minimal effect of risk communication between supervisors and subordinates in a wood manufacturing factory (Michael, Guo, Wiedenbeck, & Ray, 2006). This could be explained by challenges involved in risk communication such as level of literacy, cultural values and language barriers especially in places where the workforce consists mainly of migrant workers. Hence it is important for an occupational health hazard communication standard to be established in order to ensure that its objective in promoting safety awareness and perception among workers is achieved. Two studies included a critical component of a Hearing Conservation Program (HCP) which is personal noise exposure monitoring and communicating exposure levels to the workers but neither found any significant findings (Rabinowitz et al., 2011b; Seixas et al., 2011). This could be due to small sample sizes of the study population in both studies. Four studies used audiometry testing to measure outcomes. Three studies measured changes in hearing threshold level including rate of hearing loss in both ears at high frequencies (2, 3 and 4 KHz), standard threshold shift (STS): 10 dB or greater at 2, 3 or 4 kHz in the better ear and extended high frequencies (9 kHz to 18 kHz) while one study measured changes in sound attenuation performance with earplugs in both low and high frequencies (125 Hz- 8000 Hz) (Davies et al., 2008; Rabinowitz et al., 2011a; Riga et al., 2010; Takahashi et al., 2011). The varying methods used to measure hearing loss also makes it challenging to make direct comparison between studies to determine the most effective strategy to prevent noise-induced hearing loss (NIHL).

Body of evidence summary: Multifactorial interventions

Despite the poor level of evidence supporting the effectiveness of a multifactorial intervention in preventing noise-induced hearing loss (NIHL) mainly due to lack of experimental study designs including randomized controlled trials studies that will produce stronger evidence with less risk of bias. However, results from all five studies were consistent with findings across scientific literature available. Verbeek et al. (2014) and Laird et al. (2010) both concluded that interventions which combine multiple strategies are effective in noise-induced hearing loss (NIHL) prevention (Laird et al., 2012; Verbeek et al., 2015). Although the population studied varied across all five studies with a wide range of demographic characteristics, but it showed moderate to large impact especially in terms of improvement in sound attenuation of hearing protection devices, audiometric hearing threshold changes and reduced noise exposure level. Nonetheless, these results need to be applied to the target population and generalized with caution as the longest follow-up period (four years) was found in the study by Riga et al. (2010) and Rabinowitz et al. (2010) while the remaining studies focusing more on short term or immediate effects post-intervention. The body of evidence summary for this strategy is shown in Figure 2.5.

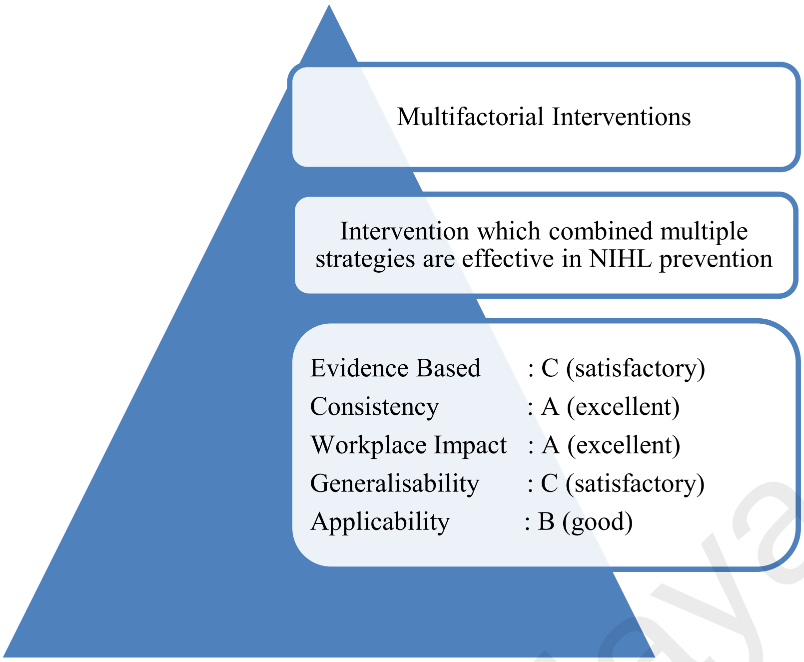
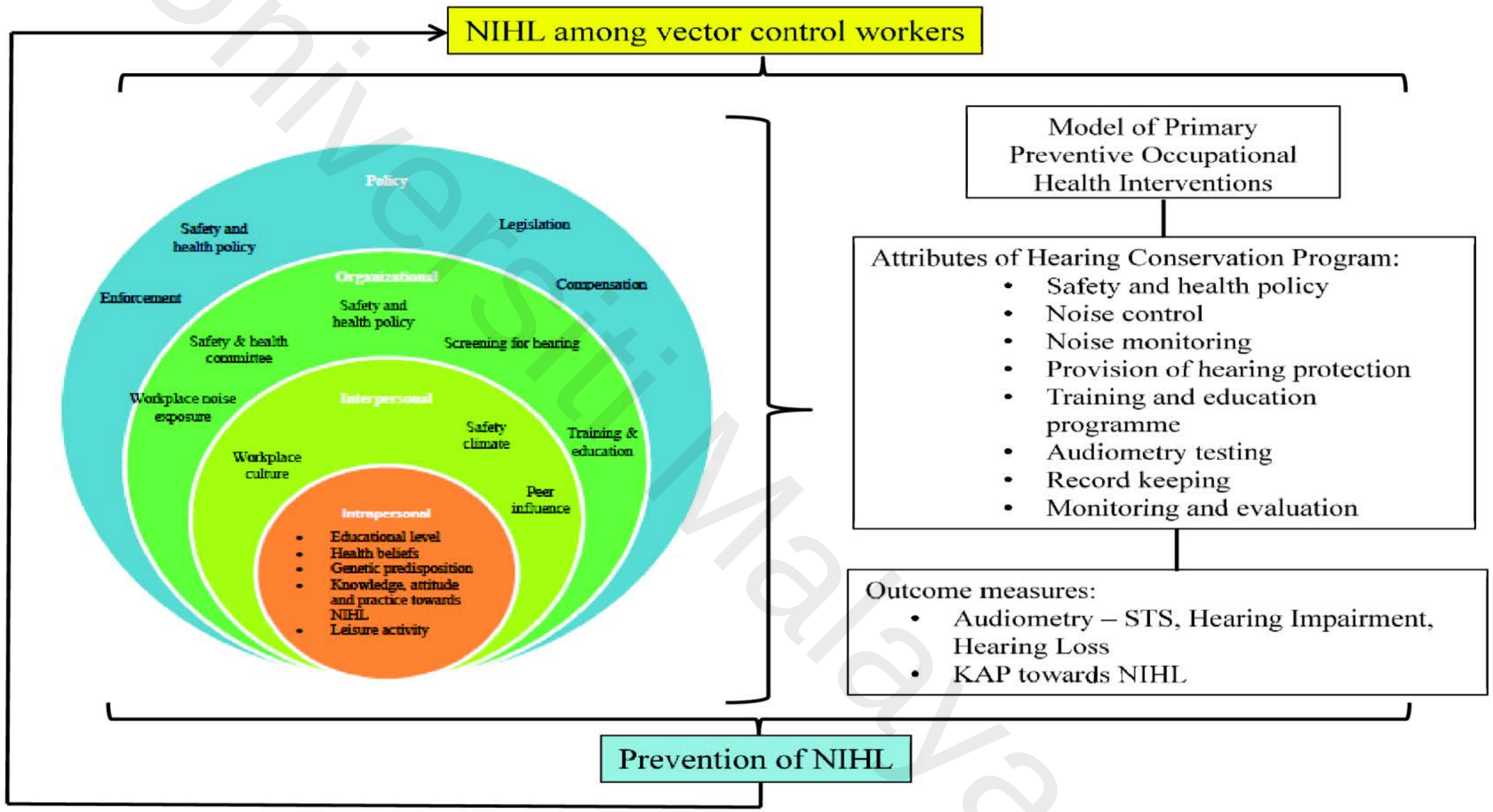


Figure 2.5: Body of evidence summary for multifactorial interventions

2.5.5 Conclusion

This systematic review identified three key strategies effective in prevention of noise-induced hearing loss (NIHL) among noise-exposed workers, the strategies are championed by leaders, one-off training and an intervention that combines multiple strategies (multifactorial intervention). All three key strategies showed positive outcomes with moderate to large impact but a comprehensive multifactorial intervention that combines multiple strategies such as a Hearing Conservation Program (HCP) is proposed as the method of choice in prevention of noise-induced hearing loss (NIHL). For an intervention to be effective it requires good organizational support or leadership especially in creating a safety climate at the workplace. One-off training showed modest immediate effects but lacked evidence on frequency or intervals for training to be delivered to workers. Although the quality of evidence is poor overall, there is good consistency with literature available and can be generalised to the population of interest but with caution as effects on different occupations are still lacking. Further research is needed to understand the long-term effects of these interventions especially since noise-induced hearing loss (NIHL) develops gradually over a long period of time.

2.6 Conceptual framework



Abbreviations: NIHL, noise-induced hearing loss; STS, standard threshold shift; KAP, knowledge, attitude and practice.

Figure 2.6: Conceptual framework

The conceptual framework for this study is based on a two models mainly the socio-ecological model and model of primary preventive occupational health interventions as shown in Figure 2.6. The socio ecological model is defined by the World Health Organization (WHO) as a theory based framework for understanding the multifaceted effects of individual and environmental factors that determine behaviours as well as identifying behavioral and organizational levels of change and intermediaries for health promotion within organizations. It can be used to explain the established risk factors for noise-induced hearing loss (NIHL) from previous literature that explains the complex interplay between factors causing NIHL at all levels (intrapersonal, interpersonal, organizational and policy) and these overlapping rings suggest that factors at a particular level can influence factors at other levels. At an intrapersonal level various factors may influence the development of hearing loss among workers such as age, leisure activities, smoking status, use of certain medications and pre-existing medical conditions. Although the majority of these factors may be controlled, certain factors remain beyond our control such as age of workers and medical conditions that may be genetically inherited. Safety practices that are critical in prevention of noise-induced hearing loss also are determined by different factors such as individual behavior and awareness that are influenced by organizational factors including providing personal protective equipment (hearing protection devices) as well as training on proper usage of personal protective equipment for workers. Meanwhile organizational factors including providing training and education to workers, setting up a safety and health committee and safety and health policy as well as ensuring workers exposed to noise undergo screening for hearing threshold levels, influence the occurrence of noise-induced hearing loss (NIHL) among workers. At a larger level or policy level, proper regulations and legislations such as the Noise Regulation 1989 that is enforced by the Department of Occupational Safety and Health (DOSH) Malaysia also play a pivotal role in prevention of noise-induced hearing loss. The consideration of interplay between various factors at different levels within this model is particularly important in creating a safety climate at the workplace for workers as organizational factors besides individual behavior play a vital role in achieving this especially through implementation of programs such as a hearing conservation program. This is due to the importance of organizational support in ensuring the effectiveness of the program in achieving its objectives. Organizational support for hearing conservation programs can be in the form of finances, safety and health policy, providing training and education to workers as well as implementing appropriate control measures to reduce noise exposure. The socio-ecological model is also helpful in identifying cluster intervention strategies especially for hearing loss prevention strategies. Besides that this model allows managers to identify key barriers to hearing conservation of workers at each level and address them effectively. The dynamic interplay between the four levels of this model affects the health outcome of individuals and must be taken into consideration as their effect on an individual's health may differ depending on individual factors, perceptions of environmental controllability, safety and health practices and financial resources (Stokols, 1996). Thus it is clear that incidence of hearing loss among workers is influenced by various factors in a smaller environment (microsystem) to a larger environment (macrosystem). The factors vary from individual factors such as genetic, hobbies, smoking, age and pre-existing medical conditions to interactions with factors in a larger environment such as workplace and organizations including policies and legislations (Tudge, Mokrova, Hatfield, & Karnik, n.d.).

One of the major strengths of the socio ecological model is its approach to health promotion that integrates individual behavioural change strategies and enhancement of surrounding environment. The workplace has been established as a built environment that carries many potential hazards and hence is a priority setting for health promotion as it directly influences the physical, mental, economic and social well-being of workers. Besides that, the workplace also offers an ideal setting for health promotion of a larger population. Workplace health promotion has also been long recognized by the World Health Organization (WHO) as a vital part of occupational health. The "Ottawa Charter for Health Promotion" identified five areas for priority action to achieve good health which includes building healthy public policy and creating supportive environments including the workplace environment. An example of healthy public policy includes workplace safety and health regulations or policy aimed at ensuring good health of workers. Hence, basic occupational safety and health programs including hearing conservation programs are considered a form of health promotion at the workplace. The concept of health promotion at the workplace is getting more attention in recent years with more private and public sectors understanding that success and performance of an organization is highly influenced by health, motivation and qualification of its workers (Potvin & Jones, 2011). The socio-ecological model allows for identification of key strengths and limitations at various levels of the framework when designing designing and implementing health promotion programs to ensure its effectiveness (Stokols, 1992).

It is important to consider factors at all levels and the interaction between them in order to develop an effective occupational safety and health (OSH) intervention to prevent noise-induced hearing loss (NIHL) among vector control workers. The socio-ecological model considers environmental and human behavior besides personal attributes in influencing health outcomes. This is particularly important especially in terms of prevention of noise-induced hearing loss among noise-exposed workers since it requires a holistic approach taking into consideration the various factors that may influence hearing loss prevention among workers.

The second model used to explain this conceptual framework is the model of primary preventive occupational health interventions. Firstly, occupational health interventions may include both clinical and non-clinical interventions and can be categorized as preventive or treatment interventions. Preventive interventions can be further categorized into three main categories mainly primary, secondary and tertiary preventive interventions. The model of primary preventive occupational health intervention was chosen as a hearing conservation program is a form of primary preventive intervention aimed at preventing the occurrence of disease (hearing loss) prior to the onset or incidence of disease. In this study, the Hearing Conservation Program (HCP) is aimed at preventing vector control workers from developing noise-induced hearing loss (NIHL) as a result of exposure to excessive noise during fogging activities. On the other hand, secondary prevention is concerned with early detection of disease and intervening to slow or halt its progression and tertiary prevention is aimed at rehabilitation following impairment or disability suffered from the disease in order to improve quality of life (Heaney & Schurman, 1996).

In the field of occupational health, the main purpose of primary preventive occupational health interventions is to eliminate or decrease exposure to health hazards at the workplace or even creating a barrier to exposure, for example, use of vaccination. The idea behind these interventions is to disrupt the causal relationship between occurrence of occupational diseases or injuries and exposure to health hazards at the workplace. The model of primary preventive occupational health interventions consists of identifying risk factors or hazards at the workplace and implementing interventions that can be categorized into three major classes: environmental, behavioural and clinical to prevent occupational diseases and injuries as shown in Figure 2.7. This model provides a comprehensive framework to maintain health of workers by identifying all three types of interventions that can be used when developing any occupational health interventions (Verbeek & Ivanov, 2013). This is particularly important for occupational health interventions as they are intended to prevent occupational diseases or injuries that are influenced by various factors such as workers' behaviour and awareness towards safety and health practices, workplace environment including tools as well as clinical inteventions such as treatments and vaccination.

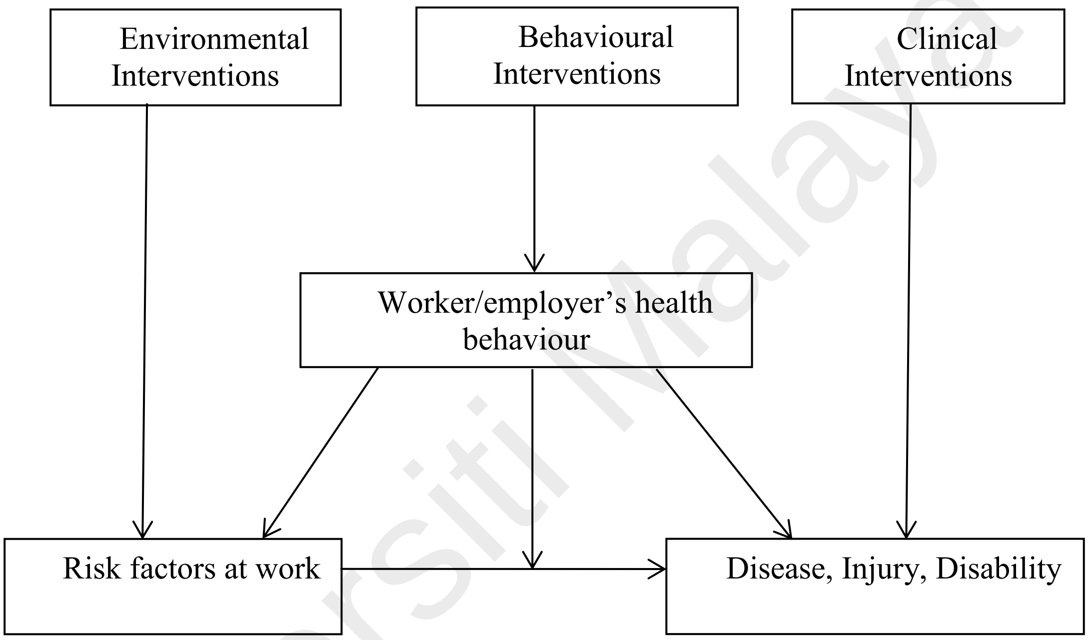


Figure 2.6: Model of Primary Preventive Occupational Health Interventions

A Hearing Conservation Program (HCP) in general is a combination of all three types of interventions (environmental, bahavioural and clinical interventions). The environmental interventions that is part of the hearing conservation program includes legislation related to permitted noise exposure levels (Noise Regulation 1989) as well as reducing noise exposure from the source by means of engineering controls such as use of noise dampening device or building barriers between noise source and worker. Noise exposure monitoring can also be categorized as part of the environmental interventions since levels of noise exposure are required to plan for appropriate control measures.

Meanwhile, the behavioural interventions that are part of this program includes health promotion on prevention of noise-induced hearing loss (NIHL) and providing training and education to workers on proper use and care of hearing protection devices. The training and education program also serves as a form of hazard communication of noise exposure assessment findings between employer and employee to raise awareness among workers. Education materials are also a form of behavioural interventions as they change workers behaviour towards safety and health practice by increasing their knowledge attitude and practice towards noise-induced hearing loss (NIHL). This will result in changes of workers behavior at the workplace such as increased use of personal protective equipment (PPE) and ensuring standard operating procedures are followed at all times. As for the clinical interventions involved in a hearing conservation program, they include pre-employment medical examination and periodic medical examination of workers' hearing. The periodic medical examination generally incorporates general medical examination and specific examination for hearing such as otoscopic examination and audiometric testing to determine workers hearing threshold level.

In summary, both the socio-ecological and primary preventive occupational health model provides researchers and guideline developers with a framework to develop a comprehensive Hearing Conservation Program (HCP) that is effective in preventing noise-induced hearing loss (NIHL) among vectors control workers that are exposed to excessive noise during fogging activities.

CHAPTER 3: METHODS AND MATERIALS

This study involves two phases, mainly development of a comprehensive Hearing Conservation Program (HCP) followed by implementation in the state of Perak and outcome evaluation to determine its effectiveness in preventing or reducing audiometric threshold changes among vector control workers as shown in Figure 3.1.

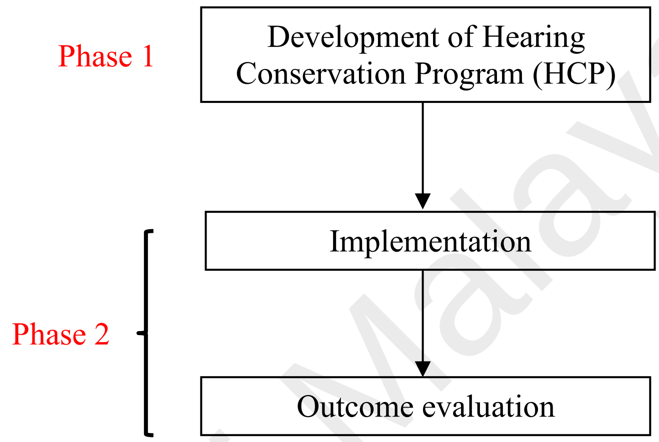


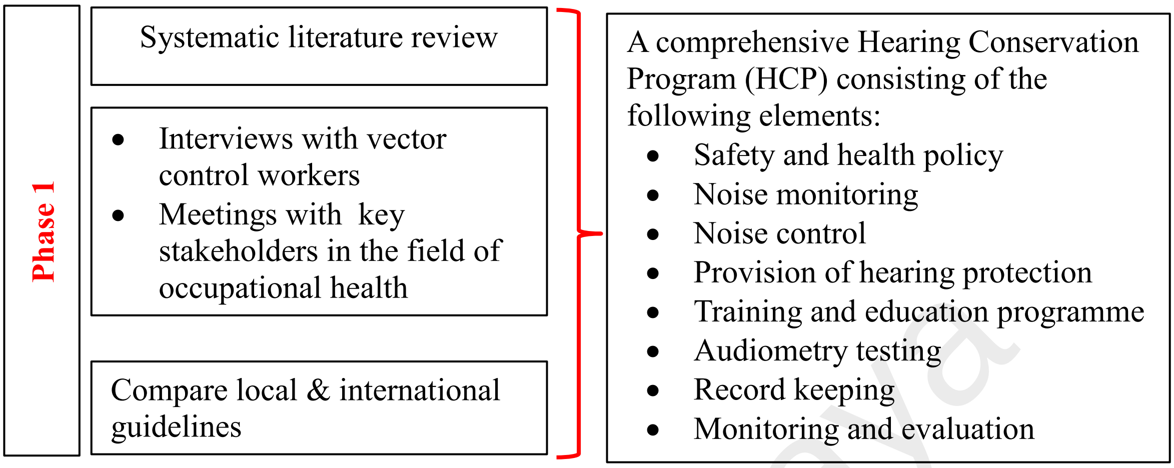
Figure 3.1: Flow diagram of development and implementation of Hearing Conservation Program

3.1 Phase 1: Development of Hearing Conservation Program (HCP)

The Hearing Conservation Program (HCP) was developed over a period of six months from May 2017 till October 2017. The hearing conservation program has been developed by synthesizing information from three key domains:

- Systematic literature review
- Comparing local and international guidelines on hearing conservation programs
- Interviews with key stakeholders and expert opinions.

The Hearing Conservation Program (HCP) development process is illustrated schematically in Figure 3.2 below.



**Key stakeholders: Ministry of Health (MOH), Department of Occupational Safety and Health (DOSH),*

Figure 3.2: Schematic representation of development of the Hearing Conservation Programme (HCP)

3.1.1 Systematic literature review

A systematic review of recent evidence on effective strategies to prevent noise-induced hearing loss (NIHL) was conducted as part of the first phase of this study which is development of a comprehensive Hearing Conservation Program (HCP). This systematic review was registered in the PROSPERO database of reviews with the registration number CRD42017064644 and is made available at https://www.crd.york.ac.uk/PROSPERO. The purpose of this systematic review is to review the evidence for effective workplace interventions to prevent NIHL among adult workers exposed to hazardous noise at the workplace which can be used in development of future noise prevention and mitigation strategies including an effective hearing conservation program.

A step-by-step approach was undertaken to ensure transparency and rigour in this systematic review process. The method for conducting this systematic review involves five steps mainly:

a) Framing the review question
b) Setting the search parameters
c) Data extraction
d) Data synthesis
e) Interpreting the findings

3.1.1.1 Review question

The review question was framed based on the PICO elements which includes:

- P (Population)

Adult workers exposed to and/or workplaces with high noise levels (i.e. more than 80 dB (A) as a time-weighted average (TWA) over a period of an entire work shift or working day or part of the work shift).

- I (Intervention)

All interventions aimed at preventing noise-induced hearing loss (NIHL) in the workplace which may consist of one or more of the following elements:

i. Engineering controls: Performing noise exposure monitoring and reducing or eliminating the noise from the source based on exposure monitoring results
ii. Administrative controls: Training and education program, organizational or management policies and supervision
iii. Hearing surveillance for workers including audiometric testing
iv. Use of personal protective equipment or personal noise protection devices

- C (Comparison)

No intervention

- O (Outcomes)

Noise exposure levels, hearing threshold levels (audiometry testing) and workers perception and acceptability of intervention.

3.1.1.2 Inclusion and exclusion criteria

The following inclusion criteria were used for selection of studies in this review:

i. Population studied are adult workers aged 19 years and above whom are exposed to noise levels more than 80 dB (A) as a time-weighted average (TWA)
ii. Only English language publications were selected
iii. Scientific literature published within the past 10 years from 1/01/2007 to 31/12/2016.
iv. No limitation of setting has been set, thus studies from all regions in the world were included in this review.

Studies were excluded if it had any of the following criteria:

i. Animal studies were not selected.
ii. Qualitative study designs
iii. Editorials, opinion pieces, commentaries, letters and conference proceedings.

3.1.1.3 Search strategy

A systematic evidence based search of scientific literature dated 1st January 2007 to 31st December 2016 was conducted in PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL) and Scopus while reviewing relevant textbooks and references from the studies selected published within the past 10 years from 1/01/2007 to

31/12/2016. These databases were selected as they are widely used among allied health professionals and easily accessible. PubMed was selected as it is easily accessible and covers a wide range of Health/Medical subjects. CINAHL database was included because it is the most widely-used and respected research tools for nurses, students and allied health professionals around the globe. Scopus was included for its extensive peer-reviewed literature and scientific journals.

In developing the search strategy for this review, three concepts were identified, in concordance with the PICO (population, intervention, comparison and outcome) statement. The concept of "Noise-induced Hearing Loss" was taken as the primary concept. Next, the concept of "Occupation" was applied to assess the volume of literature related to noise-induced hearing loss and occupation. The third concept of "Strategies to prevent noise-induced hearing loss (NIHL)" was applied to assess the volume of literature related to NIHL and occupation and strategies to prevent it. Based on the study by Verbeek et al. (2005), a search strategy was developed using keywords and search strings found to have sensitivity and specificity in locating occupational health intervention studies on reduction of noise exposure and hearing loss prevention, and additional concepts of specific interest to this literature review (Verbeek et al., 2005). The keywords related to three relevant concepts that were used in the literature search includes:

- Concept one: noise induced hearing loss, noise exposure, hearing loss
- Concept two: work, occupation, job
- Concept three: prevention, reduction, isolation, management program, engineering controls, administrative controls, personal hearing protective equipment, hearing protection device, hearing conservation, hearing surveillance, program, strategy, intervention, effect, control, evaluation

In the databases, a combination of indexed keywords and free text words were used to search and "OR" was used to connect keywords within concepts while "AND" was used to merge different concepts. To minimize irrelevant results, the terms were searched in title fields only. The search was completed in June 2017 and is limited to English language scientific peer-reviewed literature published during the last 10 years up to 31st December 2016.

3.1.1.4 Data extraction and quality assessment

Authors independently scanned the titles and abstracts and excluded those not deemed relevant. Full articles were retrieved for articles that met the inclusion criteria of this review. Discrepancies in search results were resolved by discussion among authors. For each study included, data was extracted and risk of bias was assessed by the authors. Data was extracted using a standard form (see Appendix A) that included information on study characteristics (study design, randomization methods), setting, sample population, interventions and outcomes.

The quality of evidence extracted on strategies to prevent noise-induced hearing loss (NIHL) was evaluated using a body of evidence matrix as outlined by the National Health and Medical Research Council (NHMRC) 2009 levels of evidence and grades for recommendations for developer of guidelines (Australian Government, 2009). This matrix allows evaluation of each study based on five major components which includes evidence base, consistency, impact (size of the effect of the intervention), generalisability and applicability. The components described are rated according to the matrix shown in Table 3.1.

Table 3.1: NHMRC Body of Evidence Matrix (modified for review questions)

Component	A	B	C	D
	Excellent	Good	Satisfactory	Poor
Evidence base	One or more level I studies with a low risk of bias or several level II studies with a low risk of bias	One or two level II studies with a low risk of bias or a SR/several level III studies With a low risk of bias	One or two level III studies with a low risk of bias, or level I or II studies with a moderate risk of bias	Level IV studies, or level I to III studies/SRS with a high risk of bias
Consistency	All studies consistent	Most studies consistent and inconsistency may be explained	Some inconsistency reflecting genuine uncertainty around clinical question	Evidence is inconsistent
Impact	Very large	Substantial	Moderate	Slight or restricted
Generalisability	Population/s studied in body of evidence are the same as the target population for the guideline	Population/s studied in the body of evidence are similar to the target population for the guideline	Population/s studied in body of evidence differ to target population for guideline but it is clinically sensible to apply this evidence to target population	Population/s studied in body of evidence differ to target population and hard to judge whether it is sensible to generalise to target population
Applicability	Directly applicable to Malaysian healthcare context	Applicable to Malaysian healthcare context with few caveats	Probably applicable to Malaysian healthcare context with some caveats	Not applicable to Malaysian healthcare context

The first component of this matrix (evidence base) was assessed using the following NHMRC evidence hierarchy (2009) for levels of evidence as shown in Table 3.2.

Table 3.2: NHMRC Evidence Hierarchy: designations of 'levels of evidence' according to type of research question

Level	Intervention	Diagnostic accuracy	Prognosis	Aetiology	Screening intervention
I	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies
II	A randomised controlled trial	A study of test accuracy with: an independent, blinded comparison with a valid reference standard, among consecutive persons with a defined clinical presentation	A prospective cohort study	A prospective cohort study	A randomised controlled trial
III-1	A pseudorandomised controlled trial (i.e. alternate allocation or some other method)	A study of test accuracy with: an independent, blinded comparison with a valid reference standard among non-consecutive persons with a defined clinical presentation	All or none	All or none	A pseudorandomised controlled trial (i.e. alternate allocation or some other method)
III-2	A comparative study with concurrent controls: • Non-randomised, experimental trial • Cohort study • Case-control study • Interrupted time series with a control group	A comparison with reference standard that does not meet the criteria required for Level II and III-1 evidence	Analysis of prognostic factors amongst persons in a single arm of a randomised controlled trial	A retrospective cohort study	A comparative study with concurrent controls: • Non-randomised, • experimental trial • Cohort study • Case-control study

'Table 3.2, continued'

Level	Intervention	Diagnostic accuracy	Prognosis	Aetiology	Screening intervention
III-3	A comparative study without concurrent controls: • Historical control study • Two or more single arm • study • Interrupted time series without a parallel control group	Diagnostic case-control study	A retrospective cohort study	A case-control study	A comparative study without concurrent controls: • Historical control study • Two or more single arm study
IV	Case series with either post-test or pre-test/post-test outcomes	Study of diagnostic yield (no reference standard)	Case series, or cohort study of persons at different stages of disease	A cross-sectional study or case series	Case series

Based on the individual rating for each component of the body of evidence, an overall grade of recommendation is suggested. This overall grades of recommendation are intended to indicate the strength of the body of evidence supporting the recommendation. The description of each grade of recommendation is shown in Table 3.3. A recommendation cannot be graded A or B unless the evidence base and consistency of the evidence are both rated A or B.

Table 3.3: NHMRC grades of recommendations

Grade of recommendation	Description
A	Body of evidence can be trusted to guide practice
B	Body of evidence can be trusted to guide practice in most situations
C	Body of evidence provides some support for recommendation(s) but care should be taken in its application
D	Body of evidence is weak and recommendation must be applied with caution

3.1.2 Comparing local and international guidelines

Local guidelines from the Department of Occupational Safety and Health (DOSH) Malaysia and NIOSH (Malaysia) such as the Occupational Safety and Health Act 1994, Factory and Machinery (Noise Exposure) Regulation 1989, Guidelines for Control of Occupational Noise and Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC) are reviewed and compared to international guidelines such as the NIOSH-USA Criteria for a Recommended Standard, OSHA-USA Hearing Conservation 2002, Strategies of Prevention of Deafness and Hearing Impairment by WHO and Best Practices in Hearing Loss Prevention (NIOSH-USA). A two week attachment was done at Mahidol University, Thailand in August 2017, for the purpose of comparing guidelines regarding hearing conservation programs from neighbouring countries within the

Association of Southeast Asian Nations (ASEAN) member states, a two week attachment was done at Mahidol University, Thailand in August 2017.

3.1.3 Interviews with key stakeholders

The key stakeholders engaged to develop a comprehensive Hearing Conservation Program (HCP) in this study were the Ministry of Health Malaysia and Department of Occupational Safety and Health. One of the main representatives from the Ministry of Health that was involved included the Head of Occupational and Environmental Health Sector, Ministry of Health Malaysia who is also the Chairman of the Society of Occupational and Environmental Medicine of the Malaysian Medical Association. Three meetings were held from the month of August 2017 till September 2017 to discuss the requirements for a comprehensive HCP for vector control workers in the Ministry of Health based on their job title and job description. Both these sectors play a vital role to promote and maintain the health of workers physically, mentally and socially within the Ministry of Health at the highest level. Their core activities include surveillance of occupational diseases among health care workers and promote occupational safety and health through the establishment of a Safety and Health Committee at all levels. Besides that feedback was also given from the Occupational and Environmental Health Unit, Perak during the state technical meeting prior to the implementation of the program.

Another key stakeholder that was engaged during the first phase of this study was the Department of Occupational Safety and Health (DOSH) Malaysia. The Department of Occupational Safety and Health (DOSH) Malaysia is a department under the Ministry of Human Resources and is responsible for ensuring the safety, health and welfare of people at work as well as others who face safety and health hazards in all job sectors except for those who work on board ships and the armed forces. This government agency is responsible for the administration and enforcement of legislations related to occupational safety and health mainly the Occupational Safety and Health Act 1994 and Factory and Machinery Act 1967.

Interviews with vector control workers from the Putrajaya and Titiwangsa District Health Offices were held in October 2017. Feedback from both groups of vector control workers were given after the pre-testing using a questionnaire and information obtained was important as it focused on current practices during fogging activity as well as barriers and challenges encountered by the workers during fogging activity at the field.

3.2 Phase 2: Implementation and evaluation of the Hearing Conservation Program (HCP)

3.2.1 Study design

This study is a quantitative study and the study design is a cluster randomized controlled trial.

3.2.2 Study location

This study was conducted in the state of Perak involving all 11 District Health Offices (DHO). The state of Perak is the second largest state in Peninsular Malaysia and is located north of Malaysia where it borders Kedah at the north and Selangor to the south as shown in Figure 3.3.

Figure 3.3: States of Malaysia

The capital city of Perak is Ipoh with a total population of 2.35 million people according to the population census 2010 by the Department of Statistics. It is made up of 11 districts as shown in Figure 3.4 consisting of urban and non-urban settings.

Figure 3.4: Districts of Perak

3.2.3 Study duration

This study was conducted over a period of three years from September 2016 till September 2019 and is depicted in a Gantt chart in Appendix B. The initial part of the study was spent on preparation of the proposal, getting approval from the University of Malaya Research Ethics Committee (UMREC), pretesting of questionnaire and development of the Hearing Conservation Program (HCP) that is further described in section 4.1.1. The total duration for the first phase of the study is approximately one year.

The second phase of the study included a cluster randomized controlled trial carried out over a period of 18 months to evaluate the effectiveness of the Hearing

Conservation Program (HCP). Data collection was carried out over a period of 11 months from November 2017 till September 2018. Data analysis was done during the period of October 2018 till December 2018. Data was entered and analyzed using the Statistical Package for Social Science (SPSS) software desktop version 20.0. Data was entered by a research assistant and cross-checked after completion by the researcher to identify transcription and transposition errors as well as missing data.

3.2.4 Study population

The study population for this study consists of 376 vector control workers from the District Health Offices of the Ministry of Health in the state of Perak who are involved directly with fogging activities for control of vector borne diseases and are exposed to noise hazards that are emitted from the fogging machines. This includes both permanent and contract workers from other sectors such as the Perak State Local Authority especially in the event of an outbreak or shortage of manpower.

3.2.5 Sample size

Sample size was calculated using OpenEpi version 3.01 based on two studies investigating the effectiveness of hearing conservation programs and is summarized in the table below:

Table 3.4: Sample size

Author (year)	Title	Outcome	Significant finding used	Sample size calculated
Davies et al. (2008)	The Impact of Hearing Conservation Programs on Incidence of Noise-Induced Hearing Loss in Canadian Workers	Standard Threshold Shift (STS)	Relative risk (RR) = 0.49	122
Griest et al. (2007)	Effectiveness of "Dangerous Decibels," a School-Based Hearing Loss Prevention Program	Improvement in knowledge, attitude and behaviour scores towards hearing loss.	Relative risk (RR) = 1.9	50

A calculated sample size of 122 (61 participants in each intervention and control group) was calculated based on the study by Davies et al. (Davies et al., 2008) titled "The Impact of Hearing Conservation Programs on Incidence of Noise-Induced Hearing Loss in Canadian Workers" that evaluated effectiveness of a hearing conservation program based on incidence of standard threshold shift (STS) among lumber mill workers with alpha (α) as 95% and power of the study (1- β) as 80% using OpenEpi version 3.01. The sample size was determined using the relative risk (RR) of 0.49. Since this study design is a cluster randomized controlled trial, an estimated total sample size is obtained by first determining the design effect because variability of responses in a clustered sample is reduced due to the similarity among participants within a pre-existing cluster and this similarity is expressed as the intracluster correlation coefficient (ICC). This results in the power to detect significant differences between study arms to be lowered (Killip, Mahfoud, & Pearce, 2004). Using an intracluster correlation coefficient (ICC) of 0.01 based on the study by Richard *et al.* in 2009 looking into the effectiveness of a hearing conservation program (HCP) for agricultural students (Berg et al., 2009), a design effect of 1.19 is obtained using the formula below :

$$\text{Design effect} = 1 + (n-1)p$$
$$= 1 + (20-1)0.01$$
$$= 1.19$$

n = average size of each cluster
p = intracluster correlation coefficient (ICC)

A total estimated sample size of 146 was obtained by multiplying the design effect of 1.19 with the number of participants per arm (61 participants). The total estimated sample size is inflated to 176 with 88 participants in each arm to account for a predicted attrition rate of 20%.

3.2.6 Recruitment and participant flow

Participants for both control and intervention groups were recruited from nine randomly selected District Health Offices (DHO) under the Ministry of Health (MOH) in the state of Perak (see Table 3.5 and Figure 3.4). Prior to conducting this study, the study proposal was presented at the technical meeting organised by the state health department in October 2017. The recruitment process commenced from November 2017 till January 2018 for a period of three months.

Table 3.5: List of district health offices included in this study

No	District Health Office
1	Kampar
2	Kinta
3	Manjung
4	Perak Tengah
5	Batang Padang
6	Muallim
7	Kuala Kangsar
8	Larut, Matang and Selama (LMS)
9	Hilir Perak

From a total of 279 vector control workers in the nine selected districts, 200 vector control workers agreed to join this study, giving a response rate of 65.4%. However, 17 participants were excluded because they did not have a baseline or annual audiogram for the year 2016. The inclusion and exclusion criteria for this study are as stated below.

Inclusion criteria:

i. Permanently employed and contract basis vector control workers under the Ministry of Health who are directly involved in fogging activities in the state of Perak.

ii. Able to read and understand Bahasa Malaysia.

Exclusion criteria:

i. Workers without annual audiogram for the year 2016.

ii. Vector control workers with hearing loss due to other causes besides work such as ear infection, perforated tympanic membrane and other conductive hearing loss conditions.

iii. Administrative staff that are not involved in fogging activity.

A written informed consent was obtained from all eligible participants. Prior to that, all participants were given participant information sheets containing information regarding the study (purpose, procedures, risks, benefits, alternatives to participation). Adequate recruitment and a low dropout rate of participants in both groups via close communication between researcher and participants were ensured to prevent an under powered study. This was achieved by sending reminder emails and mobile messages as well as updates on progress of the study to supervisors in charge of the vector control workers prior to data collection. Participants in both control and intervention groups were engaged at baseline (0 month), one month and three months to answer a self-administered questionnaire on sociodemographic characteristics and knowledge, attitude and practice (KAP) towards NIHL. Audiometric testing was done for participants from both groups at baseline and three months only. This is sufficient to determine the effectiveness of the intervention because the primary outcome measured is change in hearing threshold level for individual frequencies and this can be detected after a 14 hour silent period. Formal letters were also sent out to the director of each District Health Officer to ensure a directive is given to vector control workers to ensure the recruitment target is met (sample size calculated). Participants were allowed to voluntarily withdraw from participating in this study at any given time. No participants withdrew from this study. Participants that were identified to suffer from any hearing impairment during audiometric testing were referred to the nearest healthcare facility for further treatment and follow-up.

3.2.6.1 Intervention group

The intervention group participants were vector control workers that fulfilled the selection criteria from the District Health Offices in the state of Perak. The participants were randomly assigned to this group and received the Hearing Conservation Program (HCP) intervention after completion of baseline data collection. Participants from the intervention group received the intervention for a duration of three months from January 2018 till April 2018. They were required to answer a knowledge, attitude and practice (KAP) questionnaire at baseline (0 month), one month and three months as well as audiometric testing conducted at baseline (0 month) and three months.

The intervention incorporates elements of an ideal Hearing Conservation Program (HCP) tailored specifically for vector control workers and includes the following (details of the intervention are explained further under section 4.1.2):

- Hazard identification, risk assessment and risk control (HIRARC)
- Area and personal noise monitoring
- Applying noise control methods
- Distribution of appropriate hearing protection devices to each vector control worker
- Training and education program.
- Audiometric testing at baseline (0 month) and three months
- Systematic record keeping
- Program evaluation

This training and education program involved a two hour presentation, a video presentation on proper care and use of ear muffs (5 mins) and a hands-on training on proper use of ear muffs (25 mins). This training and education program contains general information in relation to noise-induced hearing loss (NIHL) and hazard communication of noise exposure monitoring results and was delivered by the researcher himself. Details of the intervention are explained further in section 4.3.

3.2.6.2 Control group

The control group participants are vector control workers from the District Health Offices in the state of Perak that met the selection criteria. The participants were randomly assigned to this group. This group did not receive any form of intervention during the study duration and continued their existing practice such as the use of hearing protection devices. At the end of the study, the control group received a similar health education program in September 2018.

3.2.7 Sampling procedure

The sampling method used for the second phase of this study is a clustered randomization method in order to achieve the target sample size of 176 participants (88 participants in each arm) from nine randomly selected District Health Offices (DHO) in Perak. Cluster random sampling is a probability sampling method. The total number of vector control workers in the whole state of Perak is 376 workers with an average of 15-30 workers per DHO. The cluster units are the DHO and out of the total 11 DHO (11 clusters) in the state of Perak, nine DHO (9 clusters) were randomly selected using computer generated random numbers with Microsoft Excel 2013. This random selection allows for equal probability for all districts in the state of Perak to be chosen. Two districts were excluded as adequate sample size was anticipated taking into account average size of each cluster or district health office. This is a one stage cluster sampling method where all the vector control workers from the selected cluster unit (DHO) were involved in the study in which four DHO were randomly assigned to the intervention group and five DHO were assigned to the control group. The advantage of this sampling method is it prevents intervention group contamination because they are geographically separated (different district). Besides that it also allows for achievement of a bigger sample with the limited resources available in terms of funding and time and is sufficient to offset the loss of precision of the study. This method also improves the accessibility of the researcher to all participants because they are in clusters and enhances participants' compliance.

3.2.8 Randomization and allocation concealment

This study uses a cluster-randomized design with District Health Offices (DHO) as the unit of randomization. Participants were randomly assigned to both arms of the study according to their district heath offices. Since this is a cluster randomization, nine out of a total 11 district health offices were randomly assigned to either the intervention or control group using a computer generated random numbers on a Microsoft Excel sheet version 2013. Out of the nine district health offices randomized, four district health offices were assigned to the intervention group (60 participants) and five district health offices being assigned to the control group (123 participants) respectively as shown in Figure 3.5 below. To ensure allocation concealment, each district heath office was first coded prior to randomization and all vector control workers from each selected district health office was included in this study. This process produced an allocation sequence in random order with each district health office as a unit of randomization having an equal chance of being assigned to either the intervention or control group.

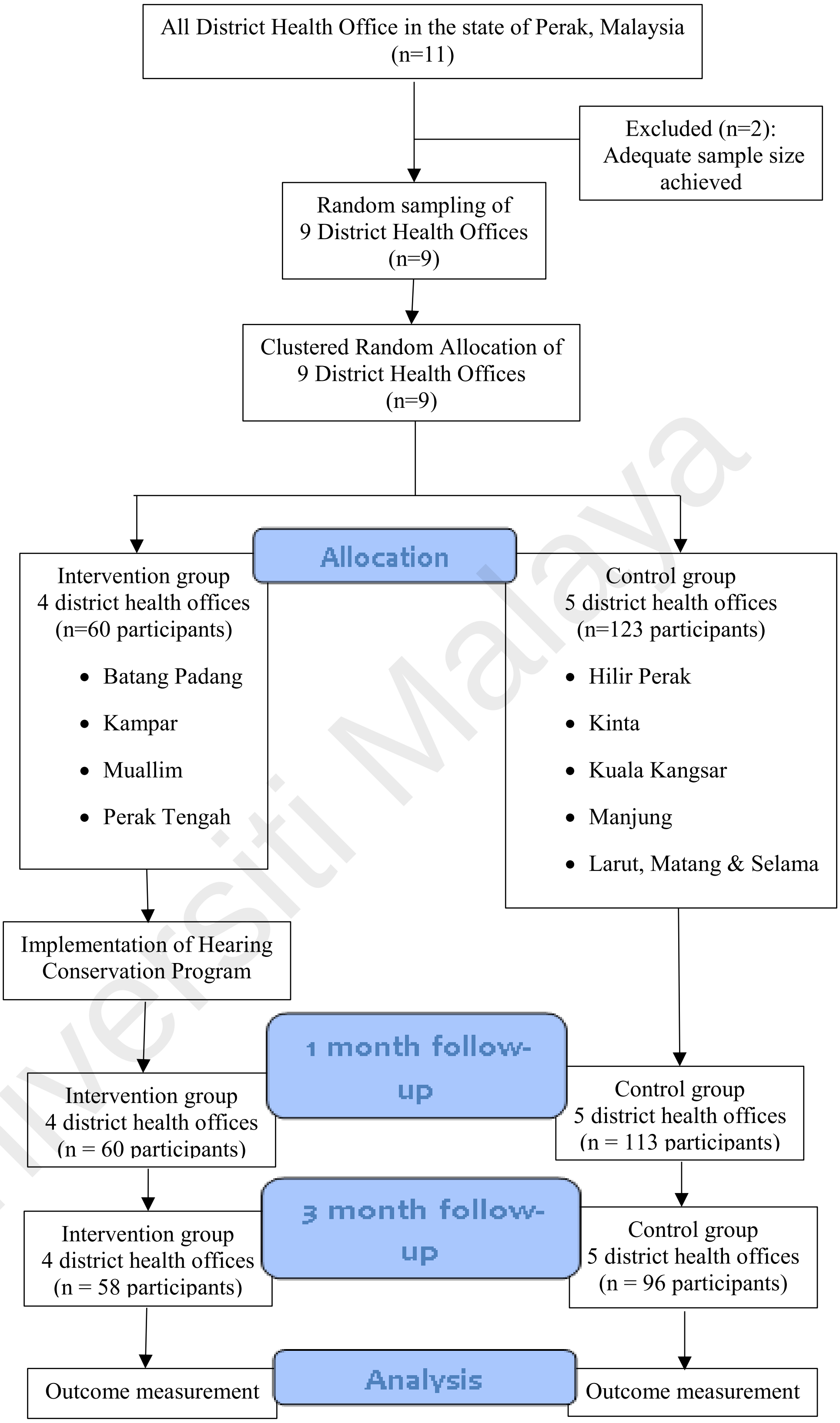


Figure 3.5: Flow diagram of study

3.2.9 Blinding

This study applies a single blinding method where data collectors and outcome assessors, mainly personnel performing the audiometry test to measure hearing threshold levels, are unaware of the group allocation of the participants for both intervention and control groups. Although baseline and three month follow-up audiometry testing for both intervention and control group were performed in the same calibrated audiometry booth, the personnel performing the audiometry tests may differ depending on availability. Nevertheless, all personnel performing the audiometry tests have received credentialing and privileging certificates from the Ministry of Health (MOH), Malaysia. Blinding of the researcher and participants is not possible as the intervention involves education and training that is delivered by the researcher. However since the intervention and control groups were from different districts and are separated geographically it is not really necessary to blind the participants in this trial. Participants were also aware of their group allocation since the intervention groups received a training and education program as part of the intervention.

3.2.10 Study variables

The study variables can be categorized into dependent and independent variables.

Dependent variables (Outcome) of this study:

- Primary outcome : Audiometric hearing threshold changes
- Secondary outcome : Knowledge, attitude and practice towards noise-induced hearing loss (NIHL)

Independent variables (sociodemographic and occupational characteristic) of this study:

- Age
- Gender
- Ethnicity
- Job title
- Duration of employment (vector unit)
- Educational level
- Average monthly household income
- Number of household members
- Occupational exposure to noise (Past and current occupation)
- Use of fogging machine
- Smoking history
- History of diving/ using guns or explosives
- Living in noisy residential area
- Tinnitus
- Ear discharge
- Difficulty to listen
- History of being treated for any hearing problems
- History of consuming ototoxic medications
- Otoscopic examination

All independent variables were categorical except age, duration of employment and average monthly household income which were continuous.

3.2.11 Operational definitions and scales of measurements

To ensure consistency in measurements of variables studied, it is important to have an operational definition outlined along with the scale of measurements as shown in Table 3.6. The operational definition for the dependent variable (outcome), audiometric hearing threshold changes is based on two criteria which is audiometry testing and workplace exposure. For audiometry testing, the audiogram must show a classic 'notch' at 4 kHz followed by recovery and an average 25 dB or more permanent hearing threshold shift at 500, 1000, 2000 and 3000 Hz compared to the standard audiometric reference level indicating hearing impairment as defined under the Noise Regulations 1989 (FMA 1967). The table below shows the operational definitions of the independent variables considered to be risk factors in developing noise-induced hearing loss (NIHL).

Table 3.6: Operational definitions of the independent variables that are tested

Variable	Operational Definition	Scale of Measurement
Age	Age of workers	Years
Gender	Socially constructed characteristics of women and men	Nominal • Male • Female
Job title	Core job performed by the workers	Ordinal • General worker • Public Health Assistant • Senior Public Health Assistant • Assistant Environmental Health Officer • Senior Assistant Environmental Health Officer • Health Inspector • Driver • Part-time worker/ contract worker
Duration of employment (vector unit)	Duration of period of work in vector control activity	Years

'Table 3.6, continued'

Variable	Operational Definition	Scale of Measurement
Ethnicity	Race of the workers	Nominal : 1 – Malay 2 – Chinese 3 – Indian 4 – Others
Education level	Highest level of formal education attained by the workers	Ordinal • No formal education • Primary • Secondary • Diploma
Average monthly household income	Salary per month according to pay slip (excluding additional income).	Ringgit Malaysia (RM)
Number of household members	Person related by birth, marriage, or adoption and residing together; all such people (including related sub-family members) are considered as members of one family.	Frequency/counts
Previous occupational noise exposure	Noise exposure during previous occupation	Nominal • Yes • No
Workplace noise exposure level	Determined using the noise dosimeter and continuous sound level of ≥ 85 dB(A) is considered a positive exposure to noise at the workplace resulting in NIHL. (According to the Noise Regulation 1989)	Continuous (Decibel)
Use of fogging machine	Current use or history of using fogging machine	Nominal • Yes • No
Smoking history	History of smoking	Nominal • Yes • No

'Table 3.6, continued'

Variable	Operational Definition	Scale of Measurement
History of diving/ using guns or explosives	History of going diving or handling guns/explosives.	Nominal • Yes • No
Living in noisy residential area	Home or place of stay located in a noisy area	Nominal • Yes • No
Tinnitus	Perception of noise or ringing in the ears.	Nominal • Yes • No
Ear discharge	Drainage of blood, ear wax, pus, or fluid from the ear	Nominal • Yes • No
Difficulty to listen	Unable to hear clearly during daily communication.	Nominal • Yes • No
History of being treated for any hearing problems	History of receiving treatment or seeking medical care for hearing related issues.	Nominal • Yes • No
History of consuming ototoxic medications	History of consuming any medications with side effects that may cause hearing loss, hyperacusis, tinnitus, and other phantom sounds and a whole host of balance problems	Nominal • Yes • No
Medical condition	Past and current medical conditions diagnosed by a registered medical practitioner	Nominal • Yes • No
Knowledge towards NIHL	Ability to identify causes, risk factors, signs and symptoms, treatment, prevention of noise- induced hearing loss and related legislation.	Ordinal • Yes • No • Don't know

'Table 3.6, continued'

Variable	Operational Definition	Scale of Measurement
Attitude towards NIHL	Ability to identify causes, risk factors, signs and symptoms, treatment, prevention of noise- induced hearing loss and related legislation.	Ordinal • Strongly agree • Agree • Neutral • Disagree • Strongly disagree
Practice towards NIHL	Initiative by worker to take preventive steps towards NIHL including use of HPD, compliance to hearing examination/audiometry testing and attending training programs.	Ordinal • Never • Seldom • Frequently • Always

3.2.12 Methods of data collection and study instrument

The data collection process was conducted over a period of ten months from December 2017 till September 2018. Data was collected using several methods mainly questionnaire, physical examination, audiometric testing and noise exposure monitoring. Participants' sociodemographic information and job characteristics data was collected during baseline screening using the questionnaire. Meanwhile environmental factors, lifestyle, past occupational history and medical condition information of participants were gathered at the three months follow-up using the hearing assessment form that is described further in section 4.1.2.6.

3.2.12.1 Knowledge, Attitude and Practice towards NIHL questionnaire

Questions regarding sociodemographic and job characteristics of the participants were combined with the knowledge, attitude and practice (KAP) questionnaire and was adopted from the study by Razman et al. (2010) with permission from the corresponding author (Razman, Naing, D, & Kamarul, 2010). This questionnaire is available in both the Malay and English language and was validated in the Malaysian population of sawmill workers with Cronbach's alpha coefficient of 0.67 (knowledge), 0.90 (attitude) and 0.75

(practice). The population studied in this study (vector control workers) have similar sociodemographic characteristics to the population in the study by Razman et al. (2010) mainly educational level. This questionnaire is a self-administered scoring questionnaire to measure knowledge, attitude and practice of vector control workers towards noise-induced hearing loss (NIHL) and pretested in a small group of vector control workers from a different location to ensure it is suitable which is further described in section 3.13. The questionnaire was administered for both control and intervention groups at baseline (before the intervention is delivered in the intervention group), one month and at three months (after the intervention has been delivered in the intervention group). This questionnaire was prepared in Bahasa Malaysia (see Appendix V) and participants were given an information sheet as well as a short briefing prior to answering the questionnaire. The information sheet contains an overview of the study, confidentiality of information shared and methods of data collection from the participants. Brief and clear instructions were also provided on the front page of the questionnaire.

Knowledge, attitude and practice towards noise-induced hearing loss (NIHL) among the vector control workers was evaluated based on the number of correct responses for each question. This questionnaire consists of 42 items that covers the three domains: knowledge (12 items), attitude (20 items) and practice (10 items) towards NIHL. For the knowledge section, categorical data was gathered such as “betul” (true), “salah” (false) and “tidak tahu” (don’t know). As for attitude items, the responses were recorded using the Likert scale ranging from 0 “sangat setuju” (strongly agree) to 4 “sangat tidak bersetuju” (strongly disagree) and for practice the responses were “tidak pernah” (never), “kadang-kadang” (seldom), “kerapkali” (frequent) and “sentiasa” (always). Scores were calculated for each domain. Scoring for knowledge items were, ‘2’ marks for a correct response, ‘1’ mark for ‘don’t know’, and no marks for an incorrect response. For positive attitude items, scores of '4', '3', '2', '1' and '0' for 'strongly agree', 'agree', 'neutral', 'disagree' and 'strongly disagree', respectively. For good practice items scores of '0', '1', '2' , and '3' are given for 'never', 'seldom', 'frequently' and 'always', respectively. The above scoring is reversed for negative attitude and practice items.

The scoring mechanism for each domain is shown in Table 3.7 below:

Table 3.7: Questionnaire scoring mechanism

Knowledge	Correct response	2
	Don't know	1
	Incorrect response	No marks
Positive Attitude	Strongly agree	4
	Agree	3
	Neutral	2
	Disagree	1
	Strongly disagree	0
Positive Practice	Always	3
	Frequently	2
	Seldom	1
	Never	0

*For negative attitude and practice items, the scores are reversed.

The total score for each domain is calculated and converted to percentage by dividing the value with the maximum total score possible for that particular domain and multiplying it by 100%. A score of 75% and above for each domain is considered to be satisfactory as proposed by Razman et al. Vector control workers who scored less than 75% are considered to lack knowledge, attitude and practice towards noise-induced hearing loss (NIHL). The increase in number of participants (%) which responded correctly to the questions for the three domains (knowledge, attitude and practice) and an increase in number of participants with satisfactory scores at one month and three month follow-ups indicates that the Hearing Conservation Program (HCP) is effective.

3.2.12.2 Physical examination

Both control and intervention group participants underwent physical examination by a registered medical doctor for bilateral ear prior to audiometry testing at baseline and three month follow up to exclude conductive hearing loss from impacted earwax and perforated tympanic membrane. Physical examination data of participants for baseline (pre- intervention) were retrieved from participant medical records from the year 2017 during their annual medical surveillance. The physical examination post-intervention (three months after delivery of intervention) was performed by the researcher who is a registered occupational health doctor. The physical examination included examination of the auditory canal and tympanic membrane of bilateral ear using an otoscope. Prior to the examination, the ear piece of the otocope is first cleaned with a medical grade alcohol based disinfectant.

The Rinne and Weber test was also performed to rule out any conductive hearing loss experienced by participants as the audiometric booths used in this study did not have the function to test for bone conduction. As an alternative, the Rinne and Weber test was performed using a 512 hertz (Hz) tuning fork to determine the type of hearing loss, conductive or sensorineural. It is a non-invasive test and is completely safe. The Rinne test was performed by striking a tuning fork and placing it on the mastoid bone behind the ear being examined and then placing it next to the respective ear canal. The participant was then asked to give a signal once the sound could no longer be heard and compare the length of time the sound was heard when the tuning fork was placed at both places mentioned. This is actually to compare air conduction time (tuning fork is placed beside ear canal) and bone conduction time (tuning fork is placed on the mastoid bone). In a normal ear, the bone conduction time is approximately twice as long as the air conduction time. In conductive hearing loss, bone conduction time is longer than the air conduction time. While in sensorineural hearing loss, the air conduction time is longer than the bone conduction time but may not be twice as long.

As for the Weber test, the tuning fork is stroked and placed on the glabella (midline of the forehead) and the participants were asked to observe if the sound is heard equally in both ears or lateralized to one ear. The findings from this test are interpreted as normal if the sound is heard equally in both ears. In conductive hearing loss, the sound will be best heard in the abnormal ear and for sensorineural hearing loss, the sound will be best heard in the normal ear.

3.2.12.3 Audiometric testing and evaluation

Audiometric testing is a vital part of a successful hearing conservation program as it serves as an effective means to measure the hearing threshold level of noise exposed workers and determine if a standard threshold shift (STS), hearing loss, hearing impairment or noise-induced hearing loss (NIHL) has occurred. Vector control workers undergo audiometric testing annually and the annual audiogram for the year 2017 (183 audiograms) was used as the baseline audiogram for this study. The audiometry testing was repeated three months after delivery of the intervention for both intervention and control groups. A total of 154 participants underwent audiometric testing three months post-intervention with 58 participants from the intervention group and the remaining 96 participants from the control group. Hearing threshold levels of the participants were assessed at the frequencies 500, 1000, 2000, 3000, 4000, 6000 and 8000 kHz. At each frequency, the hearing threshold level is recorded for each ear. Hearing threshold levels are measured in decibels (dB) with 0 decibel representing average hearing ability for adults with no ear pathology. Larger threshold values indicate poorer than average hearing. Audiometry was performed in an audiometric booth at six different health clinics (see Table 3.8) located across the state of Perak by the researcher, staff nurses or assistant medical officers with credentialing and privileging certificates for audiometric testing from the Ministry of Health, Malaysia.

Table 3.8: List of health clinics involved in audiometric testing.

No	Health Clinic	District Health Office
1	Greentown	Kampar
2	Jelapang	Kinta
3	Sitiawan	Manjung Perak Tengah
4	Tanjung Malim	Batang Padang Muallim
5	Taiping	Kuala Kangsar Larut, Matang and Selama (LMS)
6	Teluk Intan	Hilir Perak

All audiometric booths have undergone periodic calibration (see Appendix C for certificate of calibration). Participants were required to have a 14 hour silent period prior to audiometric testing and participants who had any symptoms of upper respiratory tract infection were rescheduled. Further details of the audiometric testing can be found in section 4.1.2.6.

3.2.12.4 Noise exposure levels

Noise exposure monitoring was done prior to delivery of the intervention (pre-intervention) to determine the level of noise exposure of fogging workers to noise emitted by the fogging machine. Noise monitoring or noise survey consists of area noise monitoring and personal noise monitoring. Area monitoring was performed using a calibrated Casella 63X Digital Type 2 Sound Level Meter (see Appendix D for certificate of calibration) to determine if workers are exposed to noise levels at or above the stipulated action level of 85 dB(A) and create noise mapping or noise contours for both types of fogging machines that indicates the noise sources. During the noise mapping process, noise level measurements were taken at various points to determine the distance for the noise level to reach the permissible exposure limit (PEL) and action level (AL). Precautions were taken during noise level measurements to ensure that the sound level meter was pointing towards the noise sources at a distance of 1.5 meters above ground level and one meter away from the noise source. Besides that, this noise survey was conducted in an open field to eliminate or reduce sound reflection off surfaces than can result in amplification of sound from the source during measurement of noise levels. Noise level measurements were taken at various points around the fogging machine in a stationary position mainly from the front, back, both sides, above and below. Meanwhile, personal noise monitoring was performed using a calibrated Casella dBadge2 Personal Noise Dosimeter (see Appendix E for certificate of calibration) to determine personal noise dose during the work shift sampling period or daily noise dose of vector control workers during fogging activity. The noise dosimeter was attached to four workers who were selected from both the control and intervention groups (two workers from each group), and each group had workers using either the thermal fogging machines or ULV fogging machines (one worker for each type of fogging machine). The personal noise dosimeter was clipped to the workers shirt at the shoulder region, which is within the hearing zone throughout the fogging activity and was removed at the end. Personal noise exposure monitoring was done during fogging activity which is from 5 pm to 8 pm (three hours) to calculate the daily noise dose. Prior the measurement, instructions were given to the workers to not cover the noise dosimeter microphone and to perform their duties as usual. At the end of the shift or fogging activity the personal noise exposure monitoring data including 8-hour Time-Weighted Average (TWA) and noise dose was downloaded to a computer using the Casella software. Details of the instruments used and steps in performing area noise monitoring and personal noise monitoring is further described in section 4.2.2.1. The steps for area noise monitoring are further explained in section 4.2.2.2.

3.2.13 Pre-testing of Questionnaire

The questionnaire in Bahasa Malaysia was pretested in a small group of Ministry of Health (MOH) vector control workers (66 workers) from four different district health offices in Wilayah Persekutuan Kuala Lumpur and Putrajaya State Health Department (see Table 3.9).

Table 3.9: List of health clinics involved in pre-testing of questionnaire

Date	District Health Office	Number of vector control workers	Activity
12/10/2017	Putrajaya	22	Pre-testing of questionnaire
16/10/2017	Kepong	11	Pre-testing of questionnaire
20/10/2017	Titiwangsa	16	Pre-testing of questionnaire
23/10/2017	Lembah Pantai	17	Pre-testing of questionnaire
Total		66	

Prior to answering the questionnaire, the vector control workers were given an introduction which includes purpose of the study and clear instructions on how to answer. The vector control workers were asked to complete the questionnaire and provide feedback based on their experience. The feedback received was that the questions were clear and easily understood. During the pre-testing process, it was observed that the vector control workers were attentive the whole period while showing interest untill it was complete.

3.2.14 Data analysis and interpretation of results

Prior to analyzing, data entry was performed by a research assistant. Data from approximately 20% of randomly selected questionnaires and audiometry results from each follow-up were re-entered or checked by the researcher to minimize data entry errors. Data cleaning was also done by running frequencies and comparing the observed value with those defined in labels. The outliers were detected through box plots and compared with the data sheet to check for consistency. Data was analyzed using the Statistical Package for Social Science (SPSS) software desktop version 20.0. Level of significance was set at 0.05 with all variables being tested for normality. All analysis was done based on Per-Protocol (PP) principles to avoid over-estimation in effect of the hearing conservation program since the primary outcome is measured hearing threshold levels of the participants and better reflects the effects of the intervention under ideal conditions. The baseline data on sociodemographic, occupational and environmental noise exposure, lifestyle and medical condition characteristics of the participants were analyzed separately using a chi-square test except for age and household income in which an independent t-test was used since it was continuous data. The results were presented as mean with standard deviation (SD) of the variables age and household income. The remaining qualitative variables were presented as frequency with percentages.

For the primary outcome measured (change in hearing threshold level), each individual audiogram frequency was analyzed based on the maximum change from baseline to three months and includes standard threshold shift, hearing loss and hearing impairment. The effectiveness of the program was evaluated by comparing the mean difference of hearing threshold level between pre- and post-intervention within (intragroup) and between (intergroup) the intervention and control groups using an independent t-test. This is also known as the effect size or magnitude of the difference between groups. The mean difference between control and intervention groups (intergroup mean difference) were compared and a positive intergroup mean difference indicates a greater improvement in the intervention group as compared to the comparison group.

As for the secondary outcome measured, the three main domains (knowledge, attitude and practice towards NIHL) are further categorized into 15 subdomains and the mean difference percentage score is compared for each domain between pre- and post-intervention. The differences between the intervention and control groups were tested using an independent t-test. The effectiveness of the hearing conservation program was also evaluated by comparing the proportion total percentage score of 75% and above between the intervention and control groups. A score of 75% and above is considered to be satisfactory. The increase in number of participants (%) which responded correctly to the questions for the three domains (knowledge, attitude and practice) and an increase in number of participants with satisfactory scores at one month and three months will indicate that the Hearing Conservation Program (HCP) is effective. In view of the cluster randomized design of this study, measures were taken into account for the clustering effect during analysis. The adjusted statistical values were calculated for the statistical test used by dividing the chi-squared and t-test value with design effect and subsequently, the adjusted p-values were obtained by referring to the chi-square table. This method is known as patient level analysis and increases the study statistical power by utilizing all patient level data while considering the intracluster correlation (ICC) (Campbell, Mollison, Steen, JM, & M, 2000).

3.2.15 Ethical considerations

Since the participants of this study involved human subjects, vector control workers from the District Health Offices from the Ministry of Health Malaysia in the state of Perak, ethical approval was obtained from the Medical Ethics Committee, University Malaya Medical Centre (MREC ID: 2017220-4936) on 12 April 2017 and registered with the National Medical Research Register (NMRR-17-375-34724) prior to conducting the study (see Appendix F and G). Permission to conduct this study was also obtained from the Director of the Perak State Health Department (see Appendix H). Prior to the study, all participants were given an information sheet or 'Risalah Penerangan' (see Appendix I) that contained the details of this study and its objectives. A written informed consent was obtained from all participants prior to the commencement of the study (see Appendix U). The intervention (Hearing Conservation Program) was implemented at all five District Health Offices in the control group at the end of the study. This study was supported primarily by the following grant: University of Malaya Grand Challenge (PEACE) (GC001A-14HTM) and the noise exposure monitoring instruments were sponsored by The Centre of Occupation and Environment Health (COEHUM), University of Malaya, Kuala Lumpur. The ethical codes for this study is in line with the Nuremberg Code 1947 and World Medical Association Declaration of Helsinki (Tikveel, 1949)(World Medical Association, 2001). This study has been registered with the Thai Clinical Trials Registry (TCTR) after being approved by the Thai Clinical Trials and Registry Committee and is made available at http://www.clinicaltrials.in.th/index.php?task=home with registration ID TCTR20190109002.

3.2.16 Data management

During this study, confidentiality of all participants' information was ensured. Personal information and medical records of all participants were protected by coding each participant during analysis to ensure confidentiality. Review of records, analysis and use of the data arising from this study as well as personal information was kept confidential by the investigators and not made public unless disclosure is required by law. Confidentiality of information was maintained at all times during publication and personal identity of participants will be concealed at all times to prevent direct identification of participants. Participants were not given access to personal information, study findings or other data during the study to avoid any bias that may result from acquiring this information. However, participants were informed regarding the study findings during the training program and via their superiors (Head of Departments).

The data storage is divided into two types of data, which are hard copy and soft copy data obtained via questionnaires, audiometry results, and consent forms. The hard copy data is stored in a locked filing cabinet that can only be accessed by authorised members of the research team. Hard copy data such as questionnaires and audiometric data was stored as anonymised data as the questionnaire does not have any personal identifiers on it. No copies of hard copy data was made. Both data from the questionnaire and audiometry results was transferred into soft copy data. The soft copy data was stored as anonymised data keeping personal identifiers confidential. The soft copy data is stored in the Statistical Package for Social Science (SPSS) software desktop version 20.0 format which is stored in a password protected computer that is only accessible by the researchers.

CHAPTER 4: RESULTS

The results in this chapter is presented in line with the study objectives consisting of two phases of the study:

a) Phase 1: Development the of the Hearing Conservation Program (HCP)
b) Phase 2: Implementation and evaluation of the Hearing Conservation Program (HCP) to determine its effectiveness in preventing or reducing audiometric threshold changes among vector control workers.

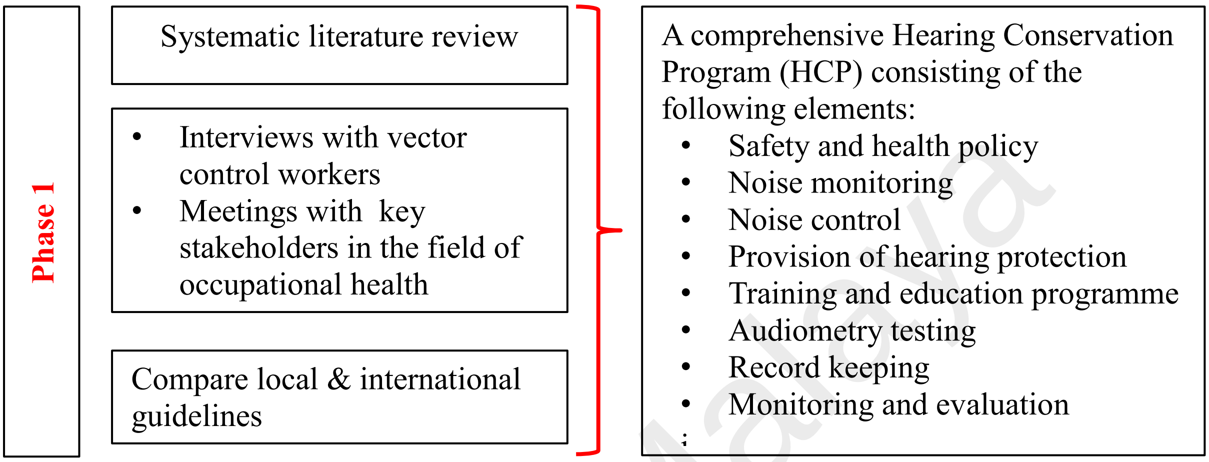
4.1 Phase 1: Development of the Hearing Conservation Program (HCP)

Hearing conservation programs (HCP) are a form of primary preventive occupational health intervention aimed at preventing noise-induced hearing loss (NIHL) (Verbeek & Ivanov, 2013). In the field of occupational health, a primary preventive intervention's purpose is to eliminate or decrease exposure of employees to hazards at the workplace and also includes administrative and environmental controls. In the event of failure of primary prevention methods, secondary prevention methods are applied, including recognizing the early stages of NIHL and taking steps to prevent its progression through intervention, follow-up screening, and clinical validation of results. Both primary and secondary preventive occupational health interventions have been shown to be effective in reducing the number of employees experiencing hearing loss (McIlwain, Gates, & Ciliax, 2008).

4.1.1 Development of the Hearing Conservation Program

The Hearing Conservation Program (HCP) was developed over a six month period from May 2017 till October 2017. The hearing conservation program was developed by synthesising information from three key domains: a systematic literature review (Chapter 2); comparing local and international guidelines on hearing conservation programs;

interviews with key stakeholders/expert opinions The Hearing Conservation Program (HCP) development process is illustrated schematically in Figure 4.1 and a description of each domain can be found in section 4.1.1.1 to 4.1.1.3. The complete description of the intervention is provided in section 4.1.2.



Key stakeholders: Ministry of Health (MOH), Department of Occupational Safety and Health (DOSH)

Figure 4.1: Schematic representation of development of the Hearing Conservation Program

4.1.2 Systematic literature review

A systematic literature review was conducted to review evidence, critically evaluate and integrate findings for effective workplace interventions to prevent NIHL among employees. The method and findings of the systematic literature review is described in detail in Chapter 2 (section 2.5). The purpose of this systematic review is to identify key strategies as well as barriers in the prevention of noise-induced hearing loss among employees at the workplace. The key strategies in preventing noise-induced hearing loss among employees identified from this systematic literature review are one-off training, championed by leaders and multifactorial approach which has been incorporated into this Hearing Conservation Program (HCP).

4.1.3 Comparing local and international guidelines

Local guidelines from the Department of Occupational Safety and Health (DOSH) Malaysia and NIOSH (Malaysia) such as Occupational Safety and Health Act 1994, Factory and Machinery (Noise Exposure) Regulation 1989, Guidelines for Control of Occupational Noise and Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC) is reviewed and compared to international guidelines: NIOSH-USA Criteria for a Recommended Standard, OSHA-USA Hearing Conservation 2002, Strategies of Prevention of Deafness and Hearing Impairment by WHO and Best Practices in Hearing Loss Prevention (NIOSH-USA). The different standards of Permissible Exposure Limit (PEL) was observed between the international and local guidelines. International guidelines have shifted to a PEL of 85 dB(A) for an 8-hour time-weighted average (TWA) with a 3 dB(A) exchange rate as compared to local guidelines applying a PEL of 90 dB(A) for an 8-hour time-weighted average (TWA) with a 5 dB(A) exchange rate. These guidelines recommend a comprehensive hearing conservation program for workers exposed to noise levels above the action level which is 85 dB according to local noise regulations to prevent hearing impairment or hearing loss (Department of Occupational Safety and Health 2005, 2008; Factory and Machineries Act 1989; McBride & Williams, 2001; National Institute for Occupational Safety and Health USA, 1999; NIOSH, 1998; Occupational Safety and Health Act and Regulations 1994, 2014; Occupational Safety and Health Administration, 2002).

In regard to comparing guidelines from neighbouring countries within the Association of Southeast Asian Nations (ASEAN) member states, a two week attachment at Mahidol University, Thailand in August 2017 showed an additional element to the hearing conservation program which is program monitoring and evaluation. Evaluation of programs is vital and needs to be carried out periodically to ensure goals or objectives of the program are achieved and delivered according to plan as well as allows improvement if needed.

4.1.4 Interviews with key stakeholders

The key stakeholders engaged to develop this comprehensive Hearing Conservation Program (HCP) were the Ministry of Health Malaysia and Department of Occupational Safety and Health. One of the key representatives from the Ministry of Health was the Head of Occupational and Environmental Health Sector, Ministry of Health Malaysia who is also the Chairman of the Society of Occupational and Environmental Medicine of the Malaysian Medical Association. Three meetings were held from the month of August 2017 till September 2017 to discuss the requirements for a comprehensive HCP for vector control workers in the Ministry of Health based on their job title and job description. Both these sectors play a vital role in promoting and maintaining the health of workers physically, mentally and socially within the Ministry of Health at the highest level. Their core activities include surveillance of occupational diseases among health care workers and promote occupational safety and health through the establishment of a Safety and Health Committee. Feedback was also sought from the Occupational and Environmental Health Unit, Perak during the state technical meeting prior to implementation of the program.

The othere key stakeholder that was engaged during the first phase of this study was the Department of Occupational Safety and Health (DOSH) Malaysia. The Department of Occupational Safety and Health (DOSH) is a department under the Ministry of Human Resources. The main responsiblity of this department is ensuring safety, health and welfare of people at work as well as others who face safety and health hazards in all job sectors except for those who work on board ships and the armed forces.

This government agency is also responsible for the administration and enforcement of legislations related to occupational safety and health mainly the Occupational Safety and Health Act 1994 and Factory and Machinery Act 1967.

Interviews with vector control workers from the Putrajaya and Titiwangsa District Health Offices was held in October 2017. Feedback from both groups of vector control workers were received after the pre-testing using a questionnaire and information obtained was important as it focused on current practices during fogging activity as well as barriers and challenges encountered by the workers during fogging activity in the field. One of the key points raised during this session was the difficulty in communicating with each other while using hearing protection devices during fogging activity and this results in improper use of hearing protection devices. This issue was encountered particularly among supervisors (Environmental Health Officers and Assistant Environmental Health Officers) whom were present during fogging activity to supervise and monitor vector control activity but do not handle the thermal fogging machine. However, being in the field during fogging activity predisposes them to excessive noise from the fogging machine and puts them at risk of developing noise-induced hearing loss in the future. Hence, they are required to use appropriate hearing protection devices but face difficulty trying to communicate and give out instructions to the general workers or “pekerja am”. The vector control workers were also unaware of their noise exposure levels and type of hearing protection devices that are suitable to be worn during fogging activity. Information such as noise exposure levels and dangers of excessive noise is vital in changing health behaviours and practice.

4.2 Phase 2: Implementation and evaluation of the Hearing Conservation Program

This section describes the findings for the second phase of the study which is the implementation and evaluation of the HCP. This results will be presented in the following sequence:

a) Baseline information (section 4.3)
b) Process evaluation (section 4.4)
c) Outcome evaluation (section 4.5)

Baseline information consists of characteristics of participants pre-intervention and is presented as below:

a) Sociodemographic characteristics of the participants
b) Occupational and noise exposure characteristics
c) Lifestyle
d) Medical condition of participants and otoscopic examination
e) Baseline hearing threshold level, Hearing Impairment and Hearing Loss
f) Knowledge, attitude and practice towards noise-induced hearing loss (NIHL)

The process evaluation was based on the following:

a) Response rate of participants
b) Attendance rate of participants from the intervention group

The final part (outcome evaluation) is an evaluation of the effectiveness of the Hearing Conservation Program (HCP) by assessing the following outcomes:

a) Audiometric threshold changes including the following:
    - Change in individual frequencies

- Change in Standard Threshold Shift (STS)
- Change in Hearing Impairment (HI)
- Change in Hearing Loss (HL)

Change in total score for each domain: knowledge, attitude and practice towards noise-induced hearing loss (NIHL)

4.3 Implementation and evaluation of the Hearing Conservation Program

The Hearing Conservation Program (HCP) was developed by incorporating information obtained from three key domains; systematic literature review, comparing local and international guidelines and interviews with key stakeholders. This Hearing Conservation Program (HCP) is aimed at preventing noise-induced hearing loss (NIHL) among vector control workers who are exposed to noise levels of more than 90 dB(A) during fogging activity. It consists of the following eight elements that is discussed further in section 4.3.2.1 to 4.3.2.8:

- Safety and health policy
- Noise monitoring
- Noise control
- Provision of hearing protection
- Training and education programme
- Audiometry testing
- Record keeping
- Monitoring and Evaluation

The Hearing Conservation Program (HCP) was implemented in all four District Health Offices (DHO) from the intervention group. This program was overseen by a HCP coordinator that was elected by the safety committee in each DHO. The HCP coordinator is answerable to the respective District Health Officer who is in charge in each district and chairs the safety and health committee. The roles and responsibilities of the HCP coordinator and employees (vector control workers) are outlined clearly.

Roles and responsibilities of the HCP coordinator includes:

- Enforcing the use of appropriate hearing protection devices (HPD) during fogging activities.
- Ensuring HPDs are maintained and are fitted and used correctly.
- Ensuring the HPDs provide adequate attenuation (noise reduction rating is adequate).
- Proper care of HPDs, including storage, location of supply, proper use and replacement of hearing protection devices.
- Ensure vector control workers are provided with adequate training.
- Maintaining noise exposure monitoring, audiometric testing and training records.
- Review and monitor the Hearing Conservation Program.

Roles and responsibilities of the employees (vector control workers) in this Hearing Conservation Program (HCP) includes:

- Wearing the appropriate hearing protection device during fogging activity.
- Knowledge and understanding of the consequences associated with not following company policy concerning the proper use of hearing protection.
- Proper care of hearing protection, including proper use, routine care and cleaning, storage, and replacement.
- Comply with scheduled audiometric testing.

The HCP comprises of eight elements and details of each component is outlined in section 4.3.1.1 to 4.3.2.8 below.

4.3.1.1 Safety and health policy

The Ministry of Health Malaysia has a written safety and health policy titled "Dasar Keselamatan dan Kesihatan Kementerian Kesihatan Malaysia" to ensure all healthcare workers as well as others are in a safe and healthy workplace environment. This piece of documented safety and health policy was displayed at all district health offices in the intervention group to raise awareness on safety and health at the workplace and serves as a reminder to all staff (see Appendix J). The awareness towards this policy was also raised among the Head of Departments and vector control workers through the establishment of a safety and health committee and during the training and education program (see section 4.3.1.5). This committee is chaired by the District Health Officer and the appointment of its members is done according the OSHA Act 1994. An organization chart of the committee is set up and displayed at every DHO. This committee will meet up at least once in every three months to discuss issues related to safety and health activities. All meetings or activities are documented as per requirement of the law (FMA 1967). The purpose and function of this safety and health committee is explained to all staff during training and education programs. A member from this safety committee will act as a HCP coordinator and is responsible for administering this hearing conservation program. The roles and responsibilities of the HCP coordinator and vector control workers are defined clearly and a copy is given to them.

4.3.1.2 Noise monitoring

Based on the job description of vector control workers, fogging activity was identified as the potential task that exposes them to hazardous noise. Prior to conducting quantitative noise monitoring, an initial noise hazard identification and risk assessment is necessary to identify potential noise sources such as noisy machinery and operations that may pose a potential health risk. The flowchart of this process is shown in Figure 4.2 below.

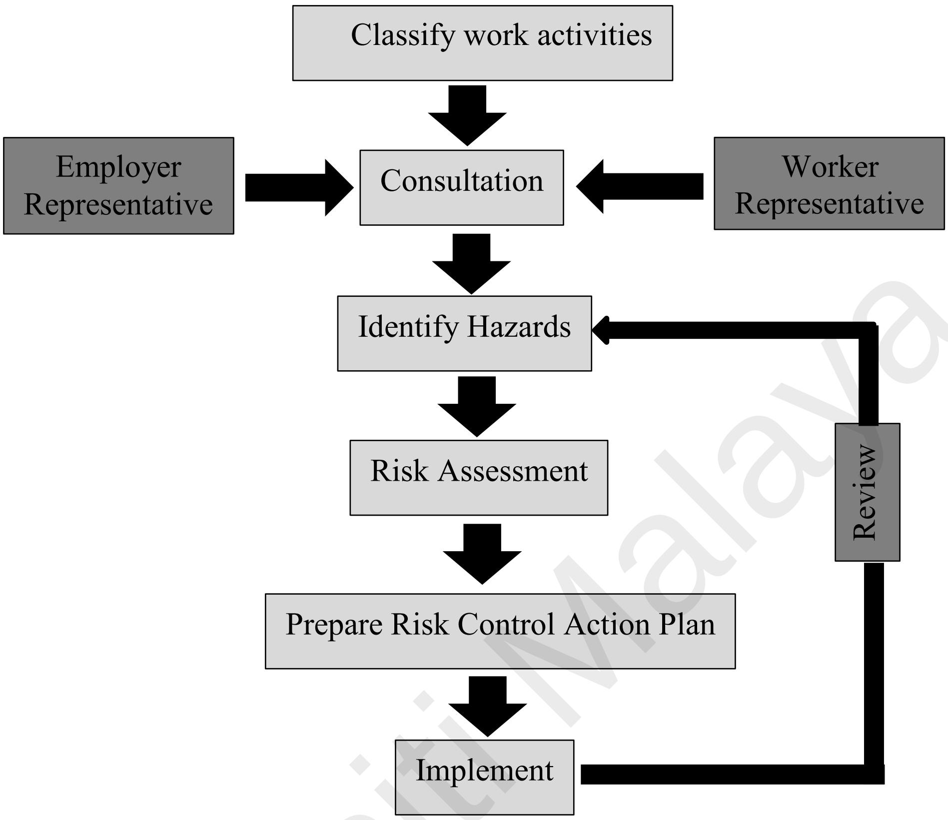


Figure 4.2: Flowchart of HIRARC Process

The initial noise hazard identification and risk assessment was done by performing a walkthrough survey and also interviewing vector control workers involved in fogging activity including their supervisors who are exposed to noise hazard. The noise hazard identification step was carried out at two district health offices (Batang Padang and Kinta) according to the Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC) and a HIRARC form was filled up (see Appendix K and L). The hazard identification was not carried out at all district health offices as the work process which is fogging activity is similar, hence one district health office was selected from each control and intervention group for this purpose. Based on the initial noise hazard identification results, potential noise sources during fogging activity was identified as the iGEBA Thermal Fogging Machine (model no: TF/AF 35) and iGEBA Ultra Low Volume (ULV) 1200 Twin Fogging Machine (model no: U 15 HD/M) used during fogging activity as shown in Figure 4.3 and 4.4.

Figure 4.3: iGEBA Thermal Fogging Machine

Figure 4.4: iGEBA Ultra Low Volume 1200 Twin Fogging Machine

A qualitative assessment of the risk during fogging activity was done according to the Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC) to determine the likelihood and severity of vector control workers developing hearing impairment or noise-induced hearing loss (NIHL) during fogging activity (Department of Occupational Safety and Health, 2008). This is important to determine the magnitude and prioritize identified hazards. Likelihood and severity is determined via the walkthrough survey and feedback from the vector control workers as well as evidence from literature on effects of noise on hearing. The risk calculated after determining the likelihood and severity of the noise hazard during fogging activity with both types of fogging machine is shown below:

4	X	3	=	12
(Likelihood)		(Severity)		(Risk)

The value of risk obtained for fogging activity using both types of fogging machine was 12 which implies medium risk (as shown in the risk matric below) to vector control workers and a planned approach is recommended to control this hazard which is discussed in section 4.2.3.

Table 4.1: Risk Matrix

	Severity (S)				
Likelihood (L)	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

'Table 4.1, continued'

(green)	Low
(yellow)	Medium
(red)	High

After the qualitative noise hazard identification and risk assessment, noise exposure levels were assessed in the same districts (Batang Padang and Kinta). Noise exposure monitoring was conducted in early January 2018 for both Batang Padang and Kinta district health offices from the intervention and control group respectively. The results are presented in the section (b) to (d) below.

(a) ***Instrumentation***

Data regarding area noise monitoring was carried out using the Casella 63X Digital Type 2 Sound Level Meter (model no: C13-CEL240) which is shown in figure 4.5. A type 2 sound level meter is more accurate for industrial field evaluations. Meanwhile, data regarding personal noise monitoring of representatives of vector control workers was performed using the Casella dBadge2 Personal Noise Dosimeter (model no: C13-DBADGE2) as shown in Figure 4.6. All the mentioned items were calibrated prior to measurement, in accordance to requirements to ensure compliance with the necessary requirements. The certificates of calibration for both devices are provided in Appendix D and Appendix E.

Figure 4.5: Casella 63X Digital Sound Level Meter

Figure 4.6: Casella dBadge2 Personal Noise Dosimeter

Data on hearing threshold levels of vector control workers were measured using a calibrated standard audiometric booth (see Appendix C for certificate of calibration) that were available at six health clinics in the state of Perak as mentioned in Section 3.12.3. The audiometric booth was equipped with a standard control panel and headphone for air conduction tests, but the bone conduction test was not available. Hence, comparisons of air conduction and bone conduction was performed manually using the Rinne and Weber test. Prior to entering the audiometric booth for pure tone audiometry testing, participants were given clear instructions to listen to tones at different pitches and volumes via headphones provided and push a button if they were able to hear them. They were also advised to focus and listen carefully as they needed to respond even if the tone sounds are very soft. Participants were instructed to undergo a 14 hour silent period or 14 hours free from workplace noise prior to audiometric testing to avoid Temporary Threshold Shift (TTS) contamination.

Figure 4.7: Audiometric booth at Tanjung Malim health clinic

(b) ***Area noise monitoring***

Noise levels were measured based on the noise sources identified previously from the HIRARC process, two noise sources identified were the thermal fogging machine and ultra-low volume (ULV) fogging machine. Precautions were taken during noise level measurements to ensure that the sound level meter was pointing towards the noise sources at a distance of 1.5 meters above ground level and one meter away from the noise source. This noise survey was conducted in an open field to eliminate or reduce sound reflection off surfaces than can result in amplification of sound from the source during measurement of noise levels. Prior to measurement of noise levels, the sound level meter settings were configured and respond time of the unit was set to "SLOW", in order to prevent sudden bursts and noise fluctuations that can affect the accuracy of noise monitoring results. The sound weighting value was also set to "A" in order to measure the range of human hearing which is between frequencies 20 Hz to 20, 000 Hz. Noise level measurements were taken at various points around the fogging machine in a stationary position from the front, back, both sides, above and below. Findings are shown in Table 4.2 and Table 4.3.

Table 4.2: Noise monitoring results of thermal fogging machine

Condition	Noise Levels (dB)					
	A	B	C	D	E	F
F	100.6	112.6	114.4	104.7	105.2	105.3

A = Front D = Right
B = Left E = Above
C = Back F = Below

Table 4.3: Noise monitoring results of ULV fogging machine

Condition	Noise Levels (dB)				
	A	B	C	D	E
Stationary	87.6	91.3	90.5	85.2	89.7

A = Front D = Right
B = Left E = Above
C = Back

The highest recorded noise level reading was 114.4 dB (A) for the thermal fogging machine from the back of the machine where the engine is located and 91.3 dB (A) for the ULV fogging machine.

(c) ***Noise mapping***

Noise mapping provides very useful information by clearly identifying areas where there are hazardous noise. For this study, noise mapping was conducted to provide vector control workers with a recommendation on a safe distance during fogging activity for those who are supervising and assisting during fogging activities but are not directly handling the thermal fogging machines, hence do not use any hearing protection devices. The noise mapping was developed by measuring the maximum weighted fast response noise level (L_{AFmax}) at various points around the thermal fogging machine determined relative to the position of the machine when placed in an open field. Noise level measurements (L_{AFmax}) were taken at 20 to 25 different positions around the machine and marked on a sketch. Noise levels noted on the sound level meter and grid spacing used in mapping were dependent on the variation of noise levels with distance from the noise source. A noise map was produced by drawing lines on the sketch between points of equal sound level and various grid/ contours were colour coded to denote the various levels of potential noise exposure as shown in Figure 4.8 and Figure 4.9.

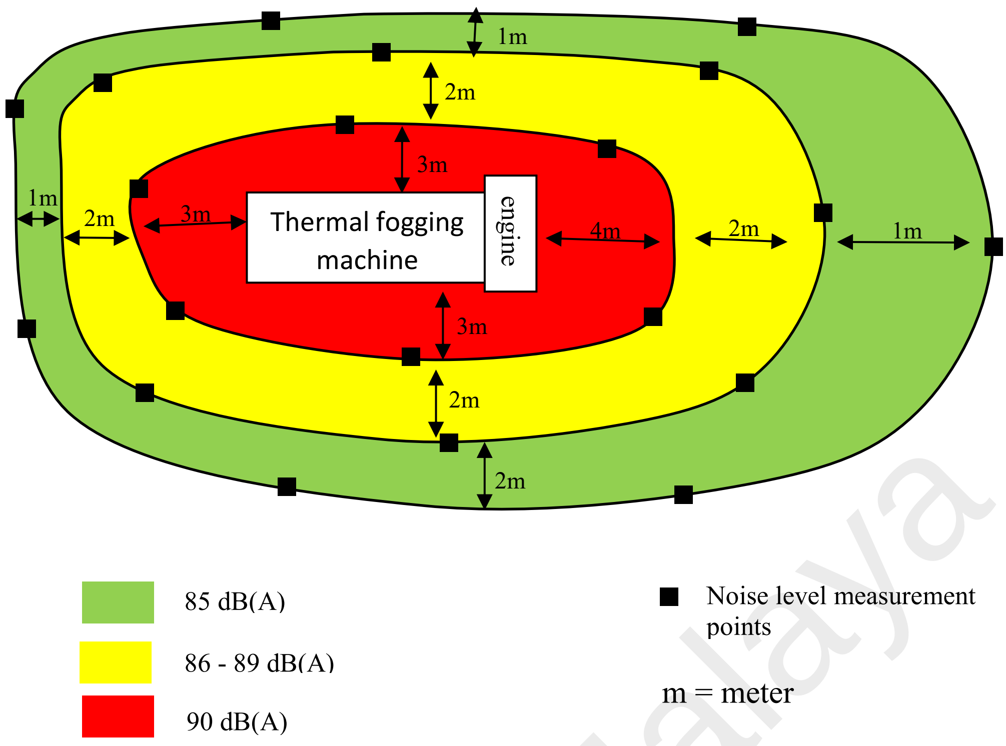


Figure 4.8: Noise mapping of thermal fogging machine

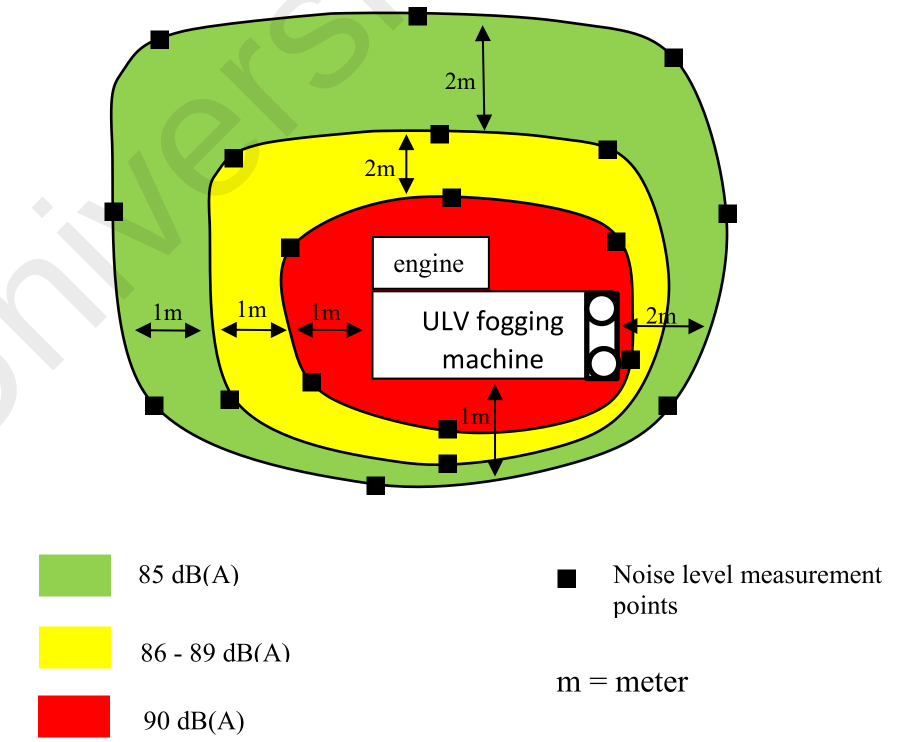


Figure 4.9: Noise mapping of ultra-low volume (ULV) fogging machine

The schematic diagram for the thermal fogging machine and ULV fogging machine are based on sequential measurements taken that helped determine the “hazard radius” or distance from the noise source to which noise level drops to the permissible exposure limit (90 dB) and action level (85 dB). Based on this, a recommended safe distance of 7 meters during fogging activity was suggested to vector workers indirectly involved during fogging activity and not using hearing protectors. This is the distance to which the noise level drops to the action level of 85 dB (A) and below, removing the workers from excessive noise exposure hence hearing protectors are not needed. This information was shared with the employer and vector control workers during the training and education program described further in section 4.3.5. Meanwhile, the vehicle mounted ULV 1200 Twin fogging machine noise mapping diagram shows higher noise levels on one side where the engine (model: Honda GX630) is located and the noise level on this side reduces to levels below the action level at a minimum distance of 2.5 meters.

(d) ***Personal noise monitoring***

After conducting area noise monitoring, four vector control workers were selected from both the control and intervention groups (two workers each from Batang Padang and Kinta), and each group had workers using either the thermal fogging machine or ULV fogging machine (one worker for each type of fogging machine). Personal exposure monitoring using a personal noise dosimeter was carried out on all four control workers selected for both thermal and ultra-low volume (ULV) fogging machines. Methods of conducting the personal noise monitoring using a noise dosimeter is described in detail in section 3.12.4. The personal noise monitoring report including Noise Dose %, Equivalent Continuous Sound Level LAeq, Maximum Level dB (A) and Peak Level dB (C) is attached in Appendix M and is summarized in Table 4.4 and 4.5 below.

Table 4.4: Personal noise monitoring results of thermal fogging machine

Group	District Health Office	$L_{EX\ 8hr}$ (dB)	LAFmax (dB)
Intervention	Worker 1 (Batang Padang)	87.3	109.8
Control	Worker 2 (Kinta)	93.1	115.8

Table 4.5: Personal noise monitoring results of ultra-low volume fogging machine

Group	District Health Office	$L_{EX\ 8hr}$ (dB)	LAFmax (dB)
Intervention	Worker 3 (Batang Padang)	79.0	97.8
Control	Worker 4 (Kinta)	70.7	92.2

The noise exposure of vector control workers for an 8-hour Time Weighted Average (TWA) is expressed as LEX 8Hrs and both workers handling the thermal fogging machine from Batang Padang and Kinta were exposed to levels above the action level of 85 dB (A) with one above the permissible exposure limit of 90 dB (A) as stated in the Noise Regulation 1989 under the Factory and Machinery Act. A daily noise dose of 100% is permitted under this regulation which is interpreted as 90 dB (A) for an 8-hour Time Weighted Average (TWA). As for the workers using the ultra-low volume (ULV) fogging machine, personal noise exposure level for an 8-hour Time Weighted Average (TWA) was well below the action level of 85 dB (A). The maximum noise level with (A) weighted frequency and FAST time constant is expressed as LAFmax. Only one worker from the control group (Kinta) using the thermal fogging machine was exposed to levels above the allowed maximum noise level of 115 dB (A) as stated under the Noise Regulation 1989 but it only exceeded by 0.8 dB. As for the peak sound level (C) from exposure to both thermal and ULV fogging machines, it is well below the permitted maximum peak noise level of 140 dB. The peak sound level (C) is usually used for occupational noise monitoring where impulsive noise is present. In contrast, the thermal and ULV fogging machines emit a continuous noise.

4.3.1.3 Noise control

Based on the noise exposure monitoring results, the vector control workers are exposed to excessive noise emitted by the fogging machines that are above the action level of 85 dB(A) as stipulated under the Noise Regulations 1989 by the Department of Occupational Safety and Health (DOSH) Malaysia. Hence there is a need for noise control measures to be in place to protect the hearing of the vector control workers during fogging activity. According to the hierarchy of control as shown in Figure 4.10, it is more effective to reduce the noise levels at the workplace from the source than to rely on hearing protection to protect workers. In terms of engineering controls, it is important for measures taken to be feasible due to limited resources available and the most suitable method of noise control identified during fogging activity is by implementing administrative controls besides the use of proper hearing protection devices.

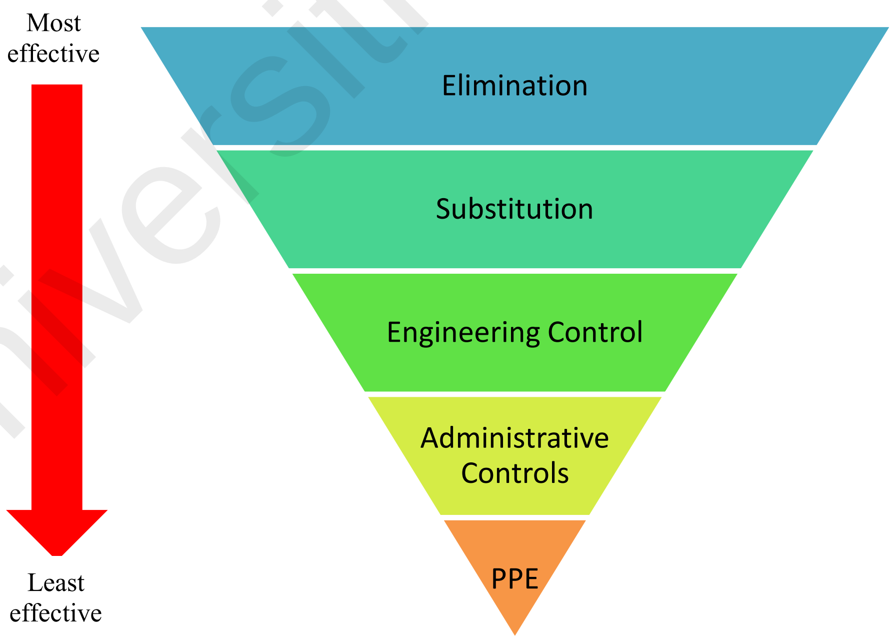


Figure 4.10: Hierarchy of controls

(a) ***Administrative control***

Despite limited resources, preventive maintenance is a must, in addition to being more reliable, it also reduces excessive noise from the fogging machine. This will also reduce failure risk and performance degradation of the fogging machine. An equipment preventive maintenance checklist is kept for each fogging machine to ensure that maintenance is conducted according to recommended intervals (see Appendix N). A sign indicating to the operator the need to wear appropriate hearing protectors is also clearly affixed to the fogging machines as shown in Figure 4.11.

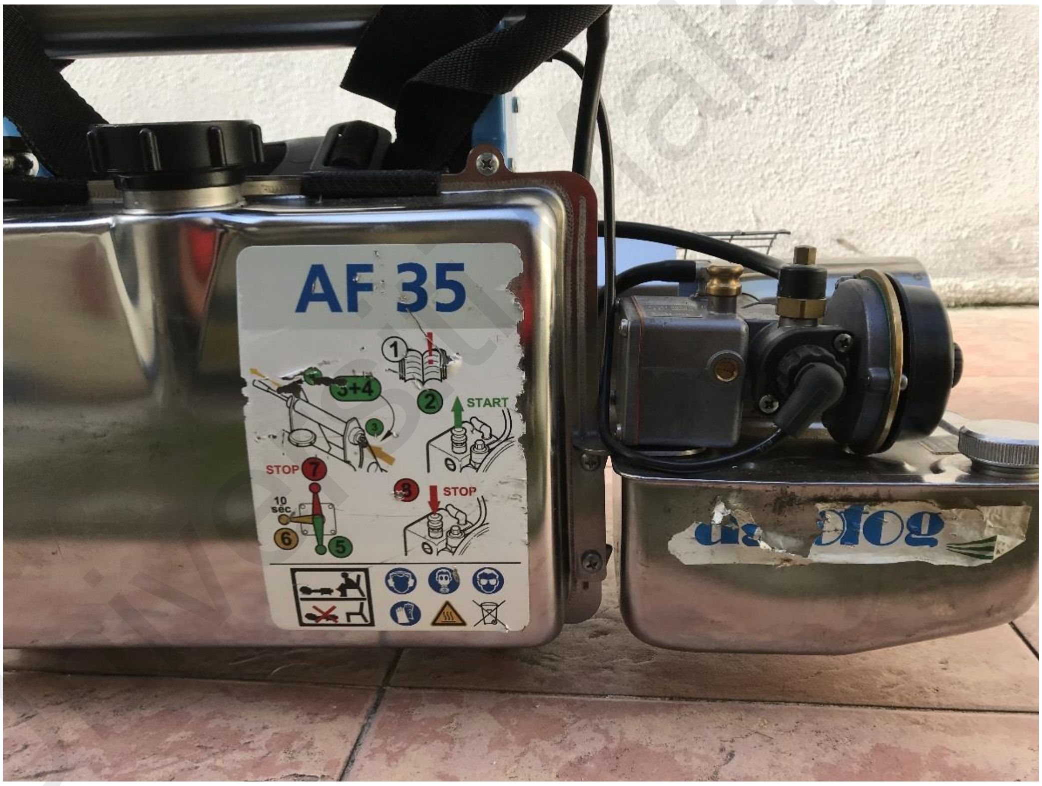


Figure 4.11: Safety signage on thermal fogging machine

Based on the noise mapping that was done; a recommended safe distance of 7 meters from the fogging machine during fogging activity is also a method of ensuring workers' noise exposure levels are below the action level of 85 dB (A). This is particularly beneficial to supervisors who need to communicate orders and other vector control workers who are not handling the fogging machine but are assisting other foggers during fogging activity, which exposes them to noise from the fogging machine as well.

4.3.1.4 Provision of hearing protection

Although engineering and administrative controls are the preferred methods for reducing noise exposure and more effective as compared to personal protective equipment (PPE) based on the hierarchy of controls but when noise levels are not reduced to limits prescribed, then there is a need for suitable hearing protectors. According to the Noise Regulation 1989, the action level for exposure to noise is 85dB (A) and appropriate Hearing Protection Devices (HPD) must be provided to employees exposed to continuous sound levels exceeding 90 dB (A) and any noise level exceeding 115 dB (A) at any time and impulsive noise of 140 dB (A). The existing hearing protectors used by the vector control workers during fogging activities are PROGUARD Ultra Ear Muffs (model: PCO5FEM) with a Single Number Rating (SNR) of 32 dB as shown in Figure 4.12 below.

Figure 4.12: PROGUARD Ultra Ear Muffs

Selection of an appropriate hearing protection device was based on the noise exposure levels detected during the noise exposure monitoring stage. Based on the personal noise monitoring results of vector control workers operating the thermal fogging machine from the Kinta District Health Office (Control Group) and Batang Padang District Health Office (Intervention Group), vector control workers are exposed to noise levels well above the permissible exposure limit (PEL) of 90 dB(A) as shown in Table 4.4. Meanwhile the personal noise monitoring results for the Ultra-Low Volume (ULV) fogging machine suggests that vector control workers are exposed to levels below the action level of 85 dB(A) as shown in Table 4.5. These low levels were mainly due to the fact that the ULV fogging machine is mounted to the back of the vehicle and workers are sitting inside the vehicle. Hence workers operating the ULV fogging machine need not wear any hearing protection devices (HPD) since the 8 hour time-weighted average (TWA) is below the action level. The permissible exposure limit (PEL) of 90 dB (A) and action level of 85 dB (A) are according to local guidelines from the Noise Regulation 1989 under the Factory and Machinery Act (1967). The level of protection or hearing protector attenuation is determined using the formula below:

Estimated 8-hour TWA with hearing protector = TWA – [(NRR - 7) / 2]
*7 is a constant
NRR = Noise Reduction Rating

Using the SNR value of 32 dB for the PROGUARD Ultra Ear Muffs (model: PCO5FEM), the estimated 8-hour time-weighted average (TWA) exposure to the thermal fogging machine is calculated and the results are shown in Table 4.6.

Table 4.6: Estimated 8-hour TWA exposure using ear muffs

Group	District Health Office	8-hour TWA (dB)	Hearing Protector	Protected 8-hour TWA (dB)	Remark
Intervention	Worker 1 (Batang Padang)	87.3	PROGUARD Ultra Ear Muffs (SNR = 32 dB)	74.8	Suitable
Control	Worker 2 (Kinta)	93.1	PROGUARD Ultra Ear Muffs (SNR = 32 dB)	80.6	Suitable

The estimated protected 8-hour TWA for workers handling the thermal fogging machine with the PROGUARD Ultra Ear Muffs is 82.9 dB and 80.6 dB respectively. This means the ear muffs reduces the vector control workers' exposure by 12.5 dB from 87.3 dB and 93.1 dB to 82.9 dB and 80.6 dB when using the thermal fogging machine. Hence, the PROGUARD Ultra Ear Muffs with a SNR value of 32 dB provides adequate protection because it reduces the vector control workers' exposure level when operating the thermal fogging machine to a level that is well below the permissible exposure limit (PEL) of 90 dB under the Noise Regulation 1989. The Hearing Conservation Program (HCP) coordinator ensured that all workers are provided with this ear muff at no cost to the employee according to Regulation 17 to Regulation 19 of the Noise Regulation 1989. The vector control workers were given training on appropriate use and care of the hearing protection devices which is further explained in the training and education section.

4.3.1.5 Training and education program

A training and education program was provided to the employers and vector control workers from the intervention group and this training program was recommended to be conducted annually and also as an orientation to all new staff. In this study, the training and education program was delivered to the intervention group by the researcher after baseline data collection was completed. A total of 60 participants from the intervention group attended the training and education program as shown in Table 4.7. Participants' attendance list is provided in Appendix O.

Table 4.7: Participants attendance for training and education program

Group	District Health Office	Date	Number of participants
Intervention	Batang Padang	16/1/2018	26
Intervention	Perak Tengah	22/1/2018	15
Intervention	Muallim	22/1/2018	11
Intervention	Kampar	23/1/2018	8
	Total		60

This training and education program involved a two hour presentation, a short video presentation on proper care and use of ear muffs (5 mins) as well as hands-on training on proper use of ear muffs (25 mins). The components of this training and education program includes:

- General information on noise and the fogging machine.
- Effects of noise on health (auditory and non-auditory effects).
- Roles and responsibilities of the Head of Departments, HCP coordinator and vector control workers in preventing NIHL.
- Purpose and function of hearing protection devices (including advantages and disadvantages).
- Information regarding noise exposure monitoring results
- Proper selection, fitting, use and care of hearing protection devices.
- Legislations regarding occupational safety and health including local noise regulation limits

Pamphlets regarding NIHL were also distributed to vector control workers in the intervention group. The pamphlets were prepared in Bahasa Malaysia (see Appendix P) and includes the following:

- General aspects and causes of hearing loss
- Risk factors of hearing loss
- Consequences of hearing loss
- Symptoms and signs of hearing loss
- Treatment of hearing loss
- Prevention
- Practice

This training and education program was delivered to participants from the control group upon completion of the study.

4.3.1.6 Audiometric testing

In this study, employee audiometric testing needed to be conducted before and after the implementation of the hearing conservation program in order to evaluate its effectiveness. The workers' annual audiometry for the year 2017 was used as baseline audiometry for this study (pre-intervention). The post-intervention audiometry was conducted during the months of April and September 2018. A total of 183 participants with baseline audiometry testing were enrolled in this study with 154 participants repeating the audiometry at the three month follow up. Audiometric testing was done in accordance to Regulation 20 to Regulation 26 of the Noise Regulation 1989 which outlines the frequency of testing, retesting and requirements of audiometric measuring equipment. Details on conducting the audiometric test is described further in section 3.2.12. All audiometric testing of the vector control workers from both intervention and control group were performed at six audiometric booths located at various health clinics across the state of Perak as shown in Table 3.5. All audiometry results were reviewed by registered occupational health doctors (OHD) at each respective health clinic and any abnormal results were referred to the nearest hospital for further evaluation and notified to the Ministry of Health. The intervention group participants received an appointment card (see Appendix Q) to serve as a reminder of upcoming medical examinations and audiometric testing. An employee audiometric test result includes a hearing assessment form (see Appendix R) that is attached along with the audiometric result and contains the following information:

- Identity and particulars of vector control worker
- Audiometry center
- Date and time of audiometric test
- Job title/ brief work description
- Medical and auditory history of the vector control worker
- Occupational history
- Ear physical examination findings
- Name of tester
- Comments from the occupational health doctor (OHD)

4.3.1.7 Record keeping

According to the Noise Regulation 1989, exposure monitoring records are to be kept for as long as the employee is employed (Regulation 29) and audiometric test records shall be retained for as long as the employee is employed and thereafter for a period of five years (Regulation 30). These records will include personal details of the vector control worker, job title, audiometric test results, noise exposure records and training records. Confidentiality of all records is upheld at all times and it is the responsibility of the administrative staff in charge and HCP coordinator to manage all these records. The following records are filed systematically and maintained in a confidential manner by the HCP coordinator:

- Noise exposure monitoring results
- Equipment maintenance records
- Hearing protection records
- Training records
- Audiometric test records
- Evaluation form

4.3.1.8 Monitoring and evaluation

`The HCP coordinator will monitor and evaluate the program annually to assess the progress and success of the hearing conservation program. This review includes feedback from vector control workers Annual reviews are documented with the form shown in Appendix S. This annual review will ensure that:

- The program is well implemented.
- Hearing conservation program objectives or outcomes are achieved.
- Identify areas that require improvements along with strength and weaknesses of the program.
- Identify barriers and challenges faced by vector control workers based on their feedback.

A simplified flow chart of implementation of this Hearing Conservation Program (HCP) is developed and displayed at all vector control units from the intervention group (see Appendix T). This flow chart provides vector control workers including the supervisors with an overview on steps to implement this program in order to ensure it is effective including key information on noise control measures.

4.4 Baseline characteristics of participants

4.4.1 Sociodemographic characteristics

There were a total of 183 vector control workers from nine district health offices from the Perak State Health Department that enrolled in this study at baseline with 60 participants in the intervention group and 123 participants in the control group. The sociodemographic characteristics of the participants from both the intervention and control groups are shown in Table 4.8. The majority of participants were males of Malay ethnicity with an average age of 37 years with 62% having up to secondary education. The only significant difference between the intervention and control groups was ethnicity. The overall average monthly household income was RM 2815 with more than 50% of participants living with less than five household members.

Table 4.8: Sociodemographic characteristics of participants

	All Frequency (%)	Intervention (n=60)	Control (n=123)	p-value
Gender				
Male	182 (99.5)	60 (100.0)	122 (99.1)	1.000[a]
Female	1 (0.5)	-	1 (0.9)	
Ethnicity				
Malay	162 (88.5)	51 (85)	111 (90.3)	
Indian	14 (7.7)	3 (5)	11 (8.9)	0.007 [a]
Others	7 (3.8)	6 (10)	1 (0.8)	
Age (years) (Mean±SD)	37.3±8.4	37.7±1.3	36.6±7.0	0.279[b]
Average monthly household income (MYR) (n=165) (Mean±SD)	2815.6±1289.9	3051.4±209.9	2703.4±106.7	0.088 [b]
<3000	101 (61.2)	33 (57.9)	68 (63)	0.615 [a]
>3000	64 (38.8)	24 (42.1)	40 (37)	
Education level				
Secondary and below	114 (62.3)	36 (60)	78 (63.4)	0.746 [a]
Tertiary	69 (37.7)	24 (40)	45 (36.6)	
Number of household members (n=179)				
1-4	99 (55.3)	33 (55.9)	66 (55)	1.000 [a]
≥5	80 (44.7)	26 (44.1)	54 (45)	

[a]Chi-square test
[b]Independent t-test

4.4.2 Occupational and noise exposure characteristics

The majority of participants were classified as general workers (50.6%) and public health assistants (35.7%) who were permanent workers with only 1.3% of total participants being contract workers with an overall mean duration of employment of 8.6 ± 11.2 years as shown in Table 4.9. In terms of noise exposure, more than half of the participants in the intervention group (55%) were exposed to noise from their previous occupations as compared to the control group but the results were not statistically significant and most participants from both groups did not live in a noisy residential area. The only significant results was use of fogging machine at work and 153 participants (83.6%) handled fogging machines in person during work which makes up most of the participants in each intervention and control group respectively.

Table 4.9: Occupational and noise exposure characteristics of participants

	All Frequency (%)	Intervention (n=60)	Control (n=123)	p-value
Duration of employment (years) (n=179) (Mean±SD)	8.6±11.2	7.5±0.9	9.3±1.3	0.656 [b]
≤2	29 (16.2)	11 (18.3)	18 (15.1)	
>2-5	50 (27.9)	20 (33.3)	30 (25.2)	
>5-10	51 (28.5)	13 (21.7)	38 (31.9)	0.442 [a]
>10	49 (27.4)	16 (26.7)	33 (27.8)	
Job title (n=154)				
i. General worker	78 (50.6)	25 (43.1)	53 (55.2)	
ii. Public Health Assistant	55 (35.7)	21 (36.2)	34 (35.4)	
iii. Senior Public Health Assistant	3 (1.9)	1 (1.7)	2 (2.1)	
iv. Assistant Environmental Health Officer	4 (2.6)	2 (3.4)	2 (2.1)	0.162[a]
v. Senior Assistant Environmental Health Officer	1 (0.7)	1 (1.7)	-	
vi. Health Inspector	2 (1.4)	1 (1.7)	1 (1)	
vii. Driver	9 (5.8)	7 (12.2)	2 (2.1)	
viii. Contract worker	2 (1.3)	-	2 (2.1)	
Past occupational exposure to noise (n=183)				
Yes	89 (48.6)	33 (55)	56 (45.5)	0.271 [a]
No	94 (51.4)	27 (45)	67 (54.5)	
Use of fogging machine (n=183)				
Yes	153 (83.6)	45 (75)	108 (87.8)	
No	30 (16.4)	15 (25)	15 (12.2)	0.034 [a]

'Table 4.9, continued'

	All Frequency (%)	Intervention (n=60)	Control (n=123)	p-value
Living in noisy residential area (n=154)				
Yes	11 (7.1)	3 (5.2)	8 (8.3)	0.537 [a]
No	143 (92.9)	55 (94.8)	88 (91.7)	

[a]Chi-square test
[b]Independent t-test

4.4.3 Lifestyle

Most of the participants (70.5%) never smoked before with 29.5% having smoked at least once in their life including ex-smokers. There were more active smokers and ex-smokers in the intervention group as compared to the control group. Meanwhile, only 14 participants (9.1%) engaged in activities associated with sensorineural hearing loss such as diving and use of guns or explosives as shown in Table 4.10 below. No significant difference was seen between groups.

Table 4.10: Lifestyle characteristics of participants

	All Frequency (%)	Intervention	Control	p-value
Smoking history (n=183)				
Yes	54 (29.5)	21 (35)	33 (26.8)	0.301 [a]
No	129 (70.5)	39 (65)	90 (73.2)	
History of diving/ using guns or explosives (n=154)				
Yes	14 (9.1)	5 (8.6)	9 (9.4)	1.000 [a]
No	140 (90.9)	53 (91.4)	87 (90.6)	

[a]Chi-square test
[b]Independent t-test

4.4.4 Medical condition of participants and otoscopic examination

A small number of participants reported hearing related issues such as tinnitus (9.7%), difficulty in listening (7.8%) and 6% of total participants had a history of being treated for hearing related conditions as shown in Table 4.11. However there were no participants that reported any discharge from the ear or use of ototoxic medications. A total of 20 participants had pre-existing medical conditions that were fairly distributed among the two groups, 12.1% (intervention group) and 13.5% (control group) respectively with a majority of them (55%) suffering from hypertension and diabetes mellitus. Otoscopic examinations revealed one participant from the intervention group having excess ear wax in his left ear but was asymptomatic and Rinne and Weber test was normal.

Table 4.11: Medical condition of participants and otoscopic examination

	All Frequency (%)	Intervention (n=58)	Control (n=96)	p-value
Tinnitus				
Yes	15 (9.7)	7 (12.1)	8 (8.3)	0.576 [a]
No	139 (90.3)	51 (87.9)	88 (91.7)	
Difficulty to listen				
Yes	12 (7.8)	7 (12.1)	5 (5.2)	0.135 [a]
No	142 (92.2)	51 (87.9)	91 (94.8)	
History of being treated for hearing problems				
Yes	6 (3.9)	2 (3.4)	4 (4.2)	1.000 [a]
No	148 (96.1)	56 (96.6)	92 (95.8)	
Medical illness				
Yes	20 (13)	7 (12.1)	13 (13.5)	1.000 [a]
No	134 (87)	51 (87.9)	83 (86.5)	
Otoscopic examination				
Right ear				
Normal	154 (100)	58 (100)	96 (100)	
Abnormal	-	-	-	
Left ear				
Normal	153 (99.4)	57 (98.3)	96 (100)	0.377 [a]
Abnormal	1 (0.6)	1 (1.7)	-	

[a]Chi-square test
[b]Independent t-test

4.4.5 Baseline hearing threshold level for all frequencies

The baseline hearing threshold level for the left and right ear of participants from both groups is shown in Table 4.12. The data is also presented in a column chart as shown in Figure 4.13 and 4.14 for better visualization and comparison between groups. For the left ear audiometry at 500 Hz, both groups recorded similar mean hearing threshold, 17.0 ± 6.7 (intervention) and 15.2 ± 7.3 (control). However, at 1000 Hz, the intervention group

(20.6 dB) recorded a higher mean hearing threshold compared to the control group (15.2 dB) and was statistically significant. At 2000 Hz frequency, the mean hearing threshold was 21.9 ± 9.3 in the intervention group and 14.4 ± 8.2 in the control group and at 3000 Hz, the mean hearing threshold was 23.8 ± 11.9 in the intervention group and 16.4 ± 9.4 in the control group. Meanwhile at higher frequencies, similar trends were observed at 4000 Hz and 6000 Hz with the intervention group having a higher mean hearing threshold compated to the control group and were statistically significant. At the 8000 Hz frequency, the mean hearing threshold was 12.6 ± 22.7 in the intervention group and 16.7 ± 15.5 in the control group.

Meanwhile, for the right ear audiometry at lower frequencies, at 500 Hz the mean hearing threshold was 22.6 ± 8.1 in the intervention group and 15.6 ± 6.1 in the control group and at 1000 Hz, the mean hearing threshold was 20.3 ± 7.8 in the intervention group and 15.1 ± 6.9 in the control group. At 2000 Hz the mean hearing threshold was 22.3 ± 12.2 in the intervention group and 14.4 ± 9.1 in the control group and at 3000 Hz, the mean hearing threshold was 22.3 ± 12.4 in the intervention group and 13.9 ± 8.2 in the control group. At higher frequencies, the intervention group had a higher mean hearing threshold compared to the control group with 25.4 dB (4000 Hz) and 22.9 dB (6000 Hz) respectively. However, at 8000 Hz, both groups shared almost similar mean hearing thresholds with 13.5 ± 22.2 (intervention) and 14.3 ± 13.5 (control) respectively.

The control group participants showed better baseline hearing threshold levels than the intervention group at all frequencies except 8000 Hz for bilateral ears. In summary, the control group showed a better hearing threshold level as compared to the intervention group for both ears pre-intervention (baseline) as shown in Figure 4.13 and Figure 4.14.

Table 4.12: Baseline hearing threshold level for all frequencies

	Left ear				Right ear			
Frequency (Hz)	All Mean (SD)	Intervention Mean (SD) (n=58)	Control Mean (SD) (n=96)	p-value	All Mean (SD)	Intervention Mean (SD) (n=58)	Control Mean (SD) (n=96)	p-value
500	15.8 (7.1)	17.0# (6.7)	15.2## (7.3)	0.148 [a]	18.1 (7.6)	22.6# (8.1)	15.6## (6.1)	$p<0.001$ [a]
1000	17.2 (8.2)	20.6 (8.5)	15.2 (7.4)	$p<0.001$ [a]	17.1 (7.7)	20.3 (7.8)	15.1 (6.9)	$p<0.001$ [a]
2000	17.2 (9.3)	21.9 (9.3)	14.4 (8.2)	$p<0.001$ [a]	17.1 (10.8)	22.3 (12.4)	13.9 (8.2)	$p<0.001$ [a]
3000	17.8 (14.0)	23.8 (11.9)	16.4 (9.4)	$p<0.001$ [a]	17.6 (11.4)	23.7 (13.8)	13.9 (7.6)	$p<0.001$ [a]
4000	21.8 (14.4)	28.9 (16.4)	17.5 (11.1)	$p<0.001$ [a]	19.9 (13.4)	25.4^ (15.7)	16.7 (10.7)	$p<0.001$ [a]
6000	22.2 (16.7)	25.7 (20.3)	20.1 (13.8)	0.036 [a]	19.7 (15.9)	22.9 (21.5)	17.8 (11.0)	0.066 [a]
8000	15.2 (18.5)	12.6^ (22.7)	16.7 (15.5)	0.191 [a]	14.0 (17.2)	13.5^ (22.2)	14.3 (13.5)	0.751 [a]

[a]Independent t-test, ^n=57; ##n=79; #n=43

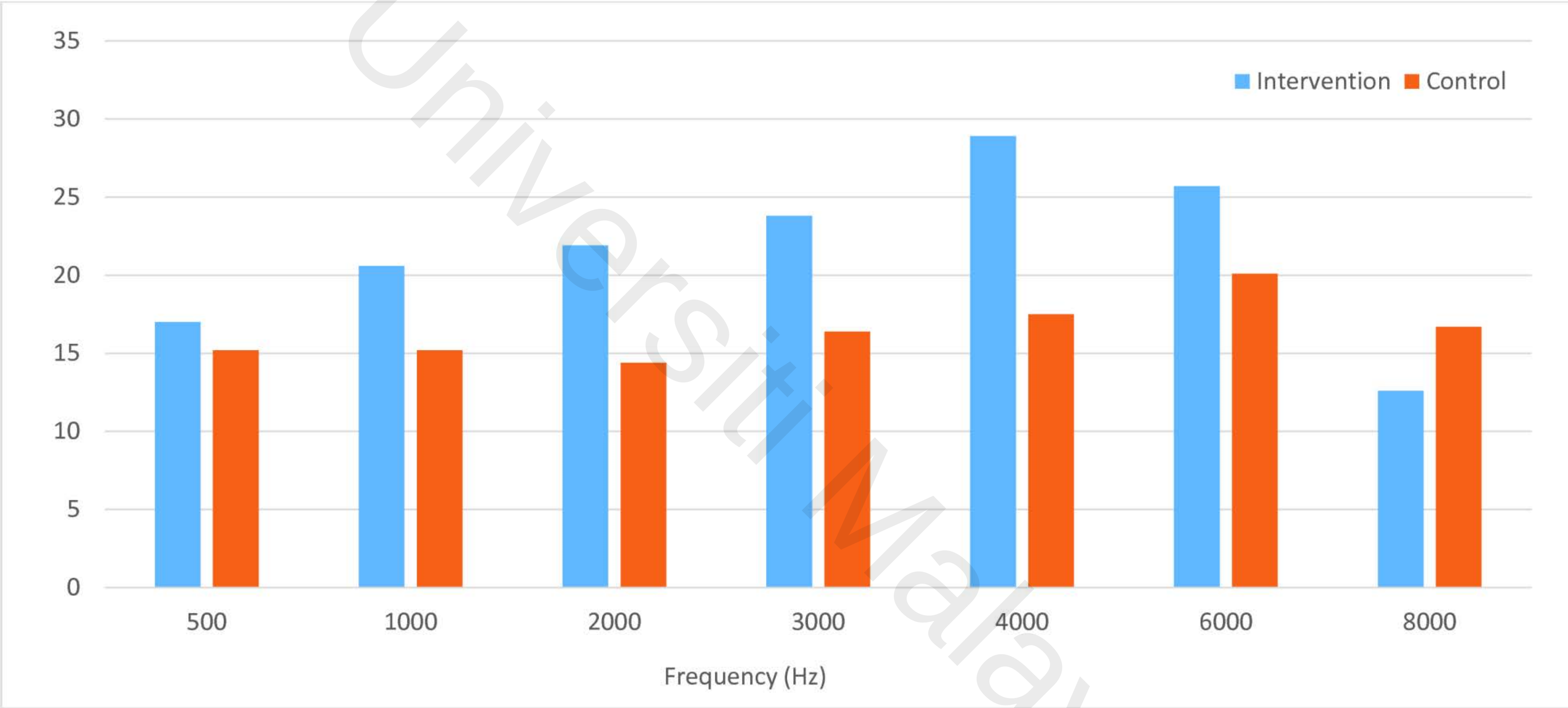


Figure 4.13: Baseline hearing threshold level of participants at 0.5 kHz to 8 kHz for the left ear

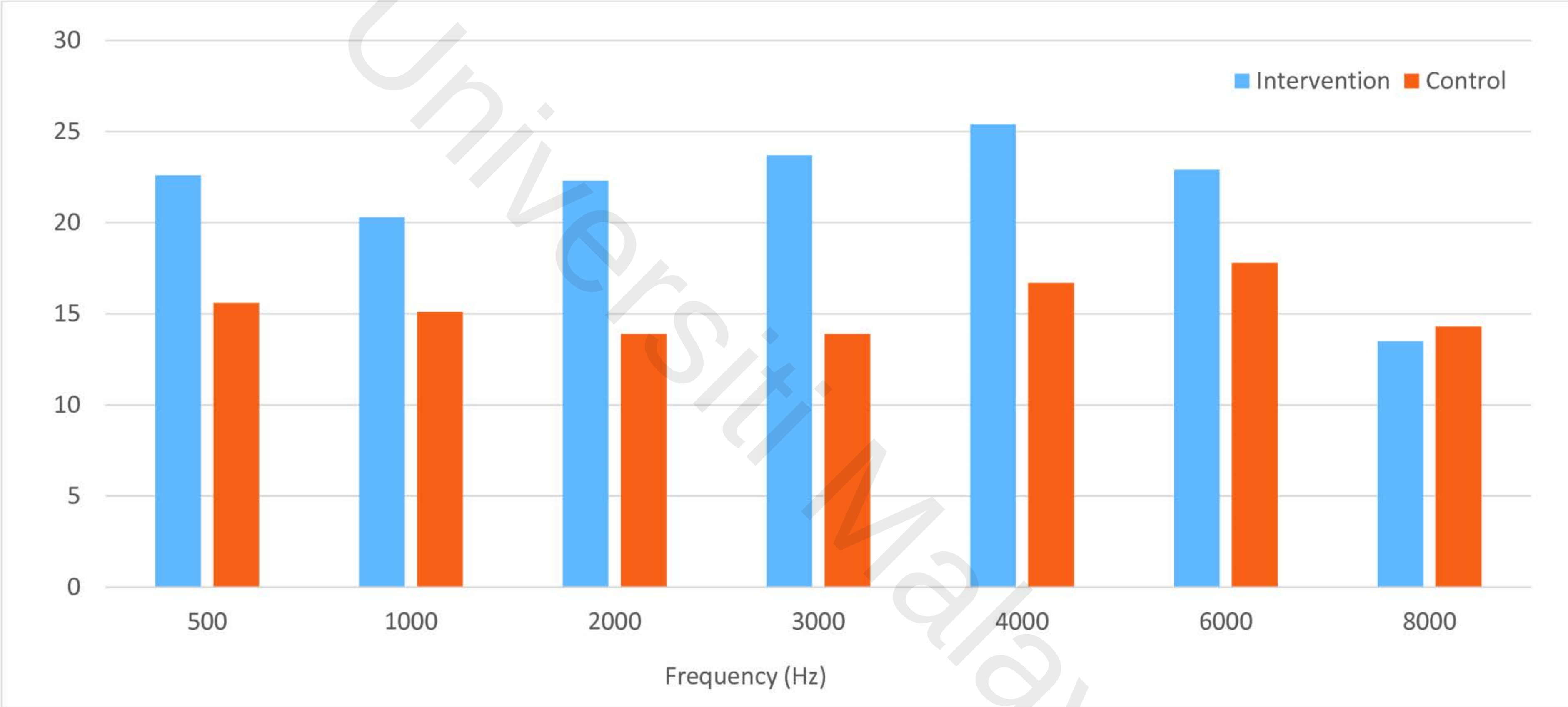


Figure 4.14: Baseline hearing threshold level of participants at 0.5 kHz to 8 kHz for the right ear

4.4.6 Baseline mean hearing threshold level at 2, 3 and 4 kHz frequency

The baseline mean hearing threshold of each participant for three frequencies (2000, 3000 and 4000 Hz) was calculated as shown in Table 4.13. For the left ear, the intervention group (24.9 dB) recorded a higher mean hearing threshold as compared to the control group (16.1 dB). Similar trends were observed for the right ear with a mean hearing threshold of 23.6 ± 13.1 (intervention) and 14.8 ± 7.9 (control). All results were statistically significant ($p<0.05$).

Table 4.13: Baseline mean hearing threshold level changes of participants at 2, 3 and 4 kHz frequency

	All Mean (SD) (n=154)	Intervention Mean (SD) (n=58)	Control Mean (SD) (n=96)	p-value
Left ear	19.4 (10.6)	24.9 (11.4)	16.1 (8.5)	p<0.001 [a]
Right ear	18.1 (11.0)	23.6 (13.1)^	14.8 (7.9)	p<0.001 [a]

[a]Independent t-test, ^n=57

4.4.7 Baseline mean hearing threshold level at 0.5, 1, 2 and 3 kHz frequency

The baseline mean hearing threshold of each participant for four frequencies (500, 1000, 2000 and 3000 Hz) was calculated as shown in Table 4.14. For the left ear, the mean hearing threshold for these frequencies are 20.8 ± 7.4 (intervention) and 15.0 ± 7.4 (control) respectively. Meanwhile, for the right ear, the mean hearing threshold for these frequencies are 22.1 ± 9.6 (intervention) and 14.1 ± 6.4 (control) respectively. All results were statistically significant ($p<0.05$).

Table 4.14: Baseline mean hearing threshold level changes of participants at 0.5, 1, 2 and 3 kHz frequency

	All Mean (SD)	Intervention Mean (SD) (n=43)	Control Mean (SD) (n=79)	p-value
Left ear	17.0 (7.8)	20.8 (7.4)	15.0 (7.4)	p<0.001 [a]
Right ear	17.0 (8.6)	22.1 (9.6)	14.1 (6.4)	p<0.001 [a]

[a]Independent t-test

4.4.8 Hearing impairment

The intervention group showed more participants at baseline with hearing impairment in the right ear with 22% as compared to 5% in the control group and is statistically significant. Similar findings were observed in the left ear with a higher proportion of participants in the intervention group (17.7%) having hearing impairment as compared to the control group (8.5%), however this result was statistically not significant as shown in Table 4.15.

Table 4.15: Proportion of participants with hearing impairment at baseline

	Left ear				Right ear			
	All	Intervention (n=45)	Control (n=94)	p-value	All	Intervention (n=45)	Control (n=94)	p-value
Normal	123 (88.5)	37 (82.2)	86 (91.5)		124 (89.2)	35 (77.8)	89 (94.7)	
Hearing impairment	16 (11.5)	8 (17.7)	8 (8.5)	0.154	15 (10.8)	10 (22.2)	5 (5.3)	0.006

4.4.9 Hearing Loss

The proportion of participants at baseline with hearing loss from both groups are shown in Table 4.16. For the left ear audiometry at 500 Hz frequency, the proportion of participants with hearing loss was 6.7% in the intervention group and 2.1% in the control group and at 1000 Hz, 11.7% of participants in the intervention group and 4.1% of participants in the control group suffer from hearing loss. Similar trends were observed at higher frequencies 2000, 3000, 4000, 6000 and 8000 Hz with a higher proportion of participants in the intervention group (16.7%, 28.3%, 38.3%, 33.3% and 22%) having hearing loss compared to the control group. The results were statistically significant at 2000 Hz – 6000 Hz. Meanwhile for the right ear audiometry at 500 Hz the proportion of participants with hearing loss was 17.8% in the intervention group and 4.2% in the control group and at 1000 Hz, 13.3% of participants in the intervention group and 2.4% of participants in the control group suffer from hearing loss. Similar trends were observed at higher frequencies 2000, 3000, 4000, 6000 and 8000 Hz with a higher proportion of participants in the intervention group (16.7%, 21.7%, 27.1%, 28.3% and 16.9%) having hearing loss compared to the control group. The results were statistically significant at 1000 Hz – 6000 Hz.

Table 4.16: Proportion of participants with hearing loss at baseline

Frequency (Hz)	Left ear				Right ear			
	All	Intervention	Control	p-value	All	Intervention	Control	p-value
500 Hz								
Normal	135 (96.4)	42 (93.3)	93 (97.9)		128 (91.4)	37 (82.2)	91 (95.8)	
Hearing Loss	5 (3.6)	3 (6.7)	2 (2.1)	0.328	12 (8.6)	8 (17.8)	4 (4.2)	0.019
1000 Hz								
Normal	171 (93.4)	53 (88.3)	118 (95.9)		172 (94.0)	52 (86.7)	120 (97.6)	
Hearing Loss	12 (6.6)	7 (11.7)	5 (4.1)	0.062	11 (6.0)	8 (13.3)	3 (2.4)	0.006
2000 Hz								
Normal	167 (91.3)	50 (83.3)	117 (95.1)		168 (91.8)	50 (83.3)	118 (95.9)	
Hearing Loss	16 (8.7)	10 (16.7)	6 (4.9)	0.012	15 (8.2)	10 (16.7)	5 (4.1)	0.007
3000 Hz								
Normal	154 (84.6)	43 (71.7)	111 (91.0)		162 (89.0)	47 (78.3)	115 (94.3)	
Hearing Loss	28 (15.4)	17 (28.3)	11 (9.0)	0.002	20 (11.0)	13 (21.7)	7 (5.7)	0.002
4000 Hz								
Normal	141 (77.0)	37 (61.7)	104 (84.6)		154 (84.6)	43 (72.9)	111 (90.2)	
Hearing Loss	42 (23.0)	23 (38.3)	19 (15.4)	0.001	28 (15.4)	16 (27.1)	12 (9.8)	0.004
6000 Hz								
Normal	143 (78.6)	40 (66.7)	103 (84.4)		149 (81.9)	43 (71.7)	106 (86.9)	
Hearing Loss	39 (21.4)	20 (33.3)	19 (15.6)	0.008	33 (18.1)	17 (28.3)	16 (13.1)	0.015
8000 Hz								
Normal	153 (84.1)	46 (78.0)	107 (87.0)		159 (87.4)	49 (83.1)	110 (89.4)	
Hearing Loss	29 (15.9)	13 (22.0)	16 (13.0)	0.133	23 (12.6)	10 (16.9)	13 (10.6)	0.240

Normal is ≤25dB; Hearing Loss is >25dB

4.4.10 Knowledge, Attitude and Practice (KAP) towards Noise-Induced Hearing Loss (NIHL)

The mean percentage score for knowledge was 77.8 ± 10.7 in the intervention group and 73.5 ± 11.7 in the control group as shown in Table 4.17. As for the attitude score, the intervention group scored higher with 75.1 ± 9.9 meanwhile the control group scored 70.7 ± 10.9. The intervention group showed satisfactory scores (≥ 75 %) for both baseline knowledge and attitude towards noise-induced hearing loss (NIHL). For the practice score, both groups scored below the satisfactory level with 62.9 ± 16.6 in the intervention group and 71.2 ± 14.3 in the control group. The only significant results were the knowledge and practice scores.

Table 4.17: Baseline percentage knowledge, attitude and practice score towards noise-induced hearing loss (NIHL)

	All (Mean±SD)	Intervention (n=60)	Control (n=123)	p-value
Knowledge score	74.9 ± 11.5	77.8 ± 10.7	73.5 ± 11.7	0.019[a]
Attitude score	73.5 ± 10.6	75.1 ± 9.9	70.7 ± 10.9	0.157[a]
Practice score	68.5 ± 15.6	62.9 ± 16.6	71.2 ± 14.3	0.001[a]

[a]Independent t-test

Figure 4.15 shows the baseline score for all three domains (knowledge, attitude and practice) and as can be seen, the intervention group showed higher scores for knowledge (77.8) and attitude (75.1) domain while the control group showed a higher average score for the practice domain with a difference of 8.3.

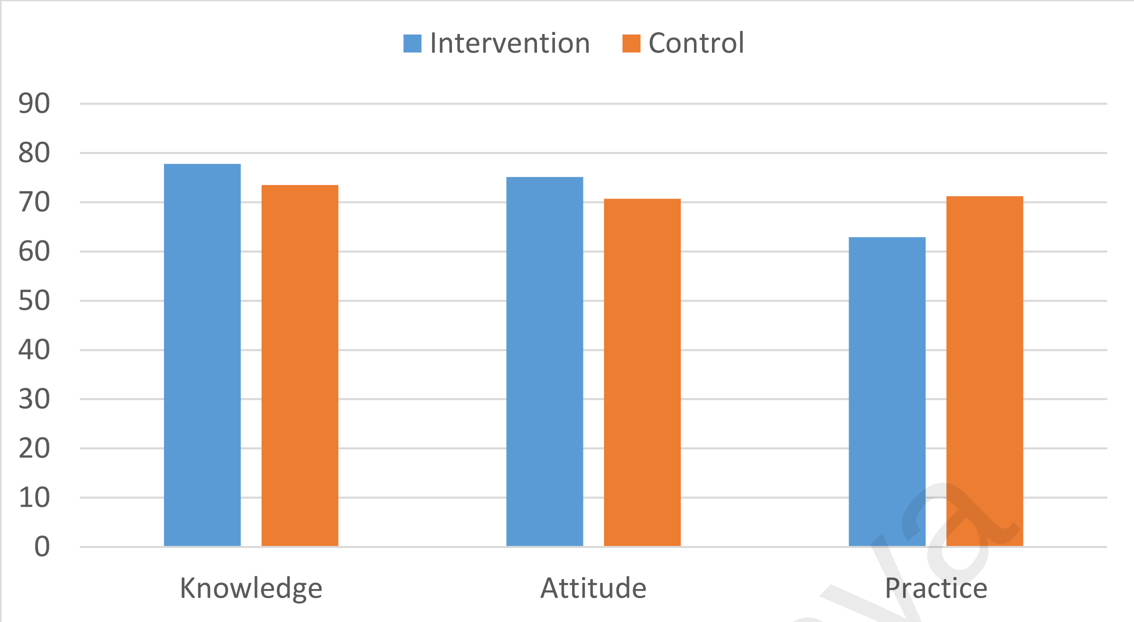


Figure 4.15: Baseline knowledge, attitude and practice score towards NIHL among participants in the intervention and control group

The score for each domain (knowledge, attitude and practice) when categorised according to satisfactory (≥75%) and unsatisfactory (<75%) scores showed a higher proportion of participants in the intervention group with satisfactory scores for the knowledge domain with 71.7% as compared to the control group with 57.7% (see Table 4.18). Similar findings were observed for the attitude domain with the intervention group (58.3%) having a higher proportion of participants with satisfactory scores as compared to the control group (47.2). Meanwhile for the practice domain, the majority of participants in the intervention group (75%) scored unsatisfactory scores with only 15 participants having satisfactory scores. The proportion of control group participants with satisfactory scores was 39%. All results were statistically not significant.

Table 4.18: Percentage of satisfactory and unsatisfactory knowledge, attitude and practice scores towards noise-induced hearing loss (NIHL)

	All Frequency (%)	Intervention (n=60)	Control (n=123)	p-value
Percentage total knowledge score				
Unsatisfactory	69 (37.7)	17 (28.3)	52 (42.3)	
Satisfactory	114 (62.3)	43 (71.7)	71 (57.7)	0.076
Percentage total attitude score				
Unsatisfactory	90 (49.2)	25 (41.7)	65 (52.8)	
Satisfactory	93 (50.8)	35 (58.3)	58 (47.2)	0.161
Percentage total practice score				
Unsatisfactory	120 (65.6)	45 (75.0)	75 (61.0)	
Satisfactory	63 (34.4)	15 (25.0)	48 (39.0)	0.069

Unsatisfactory is < 75%; satisfactory is ≥75%

4.5 Process Evaluation

4.5.1 Response rate during recruitment

The final sum of participants recruited was 183 participants who were randomly assigned to the intervention (60 participants) and control groups (123 participants). Details of the recruitment process was explained in Section 3.6. Figure 4.16 below shows the participant flow at every stage from the sampling stage till outcome measurement at baseline, one month post-intervention and three months post-intervention. Part of the intervention included a training and education program that was delivered to participants from the intervention group and the response rate was 100%. During the one month post-intervention follow-up, the response rate was 100% for the intervention group and 91.9% for the control group. For the outcome measurement at three months post-intervention follow-up, the response rate was 96.7% for the intervention group and 85% for the control group in comparison to the one month follow-up. The loss to follow-up rate is 2 (3.3%)

out of 60 in the intervention group and 27 (22%) out of 123 in the control group. Participants were lost to follow-up primarily due to being transferred to different units or simply not present during outcome measurement but the numbers were minimal.

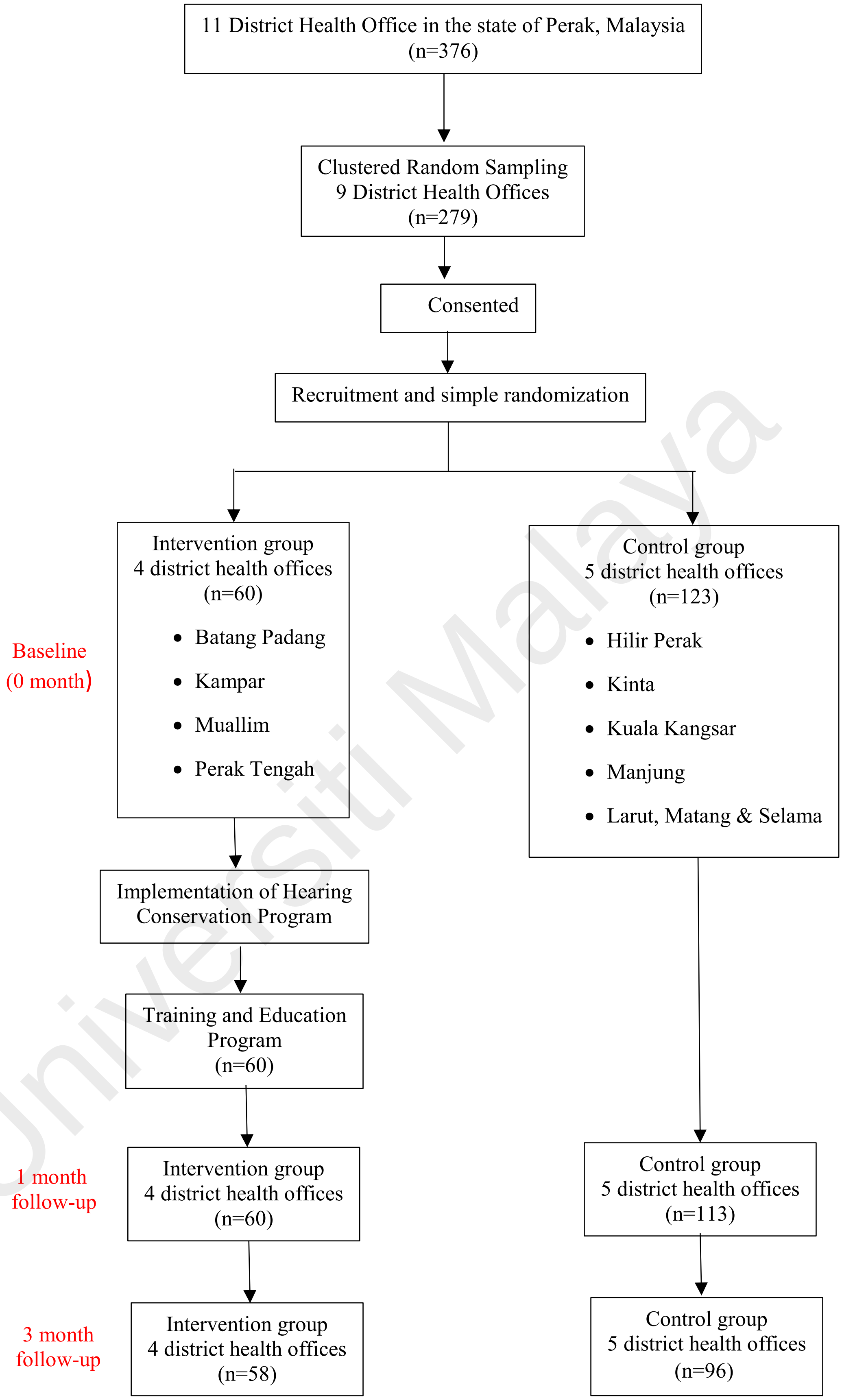


Figure 4.16: Participant flowchart

4.5.2 Characteristics of respondents and non-respondents during recruitment

Characteristics of non-respondents were measured during the recruitment phase of the study and compared with the respondents to assess for potential non-response bias as shown in Table 4.19. A total of 30 non-respondents provided information regarding baseline sociodemographic and noise exposure characteristics. Variables measured included gender, ethnicity, age, level of education, income as well as past and current exposure to noise. Findings suggest that there was no significant difference in characteristics of respondents and non-respondents for the measured variables.

Table 4.19: Characteristics of respondents and non-respondents during recruitment

	Respondent (n= 183) Frequency (%)	Non-respondent (n= 30) Frequency (%)	p-value
Gender			
Male	182 (99.5)	30 (100)	1.000
Female	1 (0.5)	0	
Ethnicity			
Malay	162 (88.5)	28 (93.4)	0.682
Indian	14 (7.7)	1 (3.3)	
Others	7 (3.8)	1 (3.3)	
Age (years) (Mean±SD)	37.3±8.4	35.2±7.6	0.201
Education level			
Secondary and below	114 (62.3)	18 (60)	0.982
Tertiary	69 (37.7)	12 (40)	
Average monthly household income (MYR) (Mean±SD)	2815.6±1289.9	2466.4±898.8	0.157
Past occupational exposure to noise			
Yes	89 (48.6)	20 (66.7)	0.078
No	94 (51.4)	10 (33.3)	
Use of fogging machine			
Yes	153 (83.6)	22 (73.3)	0.198
No	30 (16.4)	8 (26.7)	

4.5.3 Attendance of participants at training and education session

Attendance rates for the training and education sessions for participants from the intervention group are shown in Table 4.20 below. The intervention group participants (n=60) from all four district health offices from baseline attended the training and education session giving a 100% attendance. A full attendance was achieved as the training sessions were held at each district health office respectively without participants needing to travel.

Table 4.20: Attendance rate for training and education program among participants from the intervention group

District Health Offices	n	%
Batang Padang	26	100
Kampar	8	100
Muallim	11	100
Perak Tengah	15	100

4.6 Outcome evaluation

The effectiveness of the Hearing Conservation Program (HCP) in achieving its objectives was measured using outcomes such as changes in hearing threshold level at different frequencies, standard threshold shift (STS), Hearing Impairment, Hearing Loss and knowledge, attitude and practice towards noise-induced hearing loss (NIHL).

4.6.1 Hearing threshold level changes at all frequencies after three months

The intragroup and intergroup hearing threshold level changes in bilateral ear for all frequencies after three months for both control and intervention groups are shown in Table 4.21 and 4.22. The left ear mean hearing threshold in the intervention group showed significant improvement for all frequencies post-intervention with the largest reduction seen at 6000 Hz with a 5.4 dB reduction and is statistically significant ($p<0.05$). At 8000

Hz, the mean hearing threshold remained similar post-intervention with only a 0.2 dB reduction observed.

The control group also showed a reduction in left ear mean hearing threshold for all frequencies with the largest reduction seen at 500 Hz with a 3.5 dB reduction and is statistically significant ($p<0.05$). The mean hearing threshold remained similar after three months for frequencies of 4000 Hz and 6000 Hz with only a 0.8 dB and 0.6 dB reduction.

The mean difference between control and intervention groups was calculated and a positive intergroup mean difference indicates a greater improvement in the intervention group as compared to the comparison group. Positive values of intergroup mean difference were observed at 2000 Hz (0.97 dB) and 4000 Hz (2.24 dB) with greatest improvement seen at the latter frequency even though it was statistically not significant.

Table 4.21: Left ear hearing threshold level changes of participants after three months

Frequency (Hz)	Intervention group (n=58)			Control group			Intergroup	
	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Intragroup mean difference (SD)	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Intragroup mean difference (SD)	Intergroup mean difference (95% CI)	p value
500	17.0#(6.7)	15.7#(11.9)	-1.3 (10.3)	15.2##(7.3)	11.7##(8.7)	-3.5* (8.2)	-2.27 (-5.64, 1.11)	0.186
1000	20.6(8.5)	18.9 (10.7)	-1.7 (6.7)	15.2 (7.4)	12.5 (9.3)	-2.6* (8.7)	-0.90 (-3.53, 1.73)	0.500
2000	21.9(9.3)	19.1 (11.5)	-2.8* (5.8)	14.4 (8.2)	12.5 (10.1)	-1.9* (8.3)	0.97 (-1.49, 3.43)	0.437
3000	23.8(11.9)	22.7 (13.4)	-1.1 (7.4)	16.4 (9.4)	14.8 (13.6)	-1.6 (9.9)	-0.44 (-3.41, 2.53)	0.769
4000	28.9(16.4)	25.9 (15.5)	-3.0* (8.2)	17.5 (11.1)	16.7 (15.9)	-0.8 (11.3)	2.24 (-1.13, 5.60)	0.191
6000	25.7(20.3)	20.3 (19.8)	-5.4*(12.4)	20.1 (13.8)	19.5 (16.6)	-0.6 (11.6)	4.86 (0.95, 8.77)	0.015
8000	12.6^(22.7)	12.5^(19.3)	-0.2 (11.5)	16.7 (15.5)	15.3 (18.4)	-1.4 (11.1)	-1.18 (-4.90, 2.54)	0.532

*statistically significant intragroup mean difference ($p<0.05$); # n=43; ## n=79; ^ n=57
Intragroup mean difference = mean post-intervention – mean pre-intervention
Intergroup mean difference = mean difference control group – mean difference intervention group

Meanwhile for the right ear hearing threshold level, the intervention group showed an increase in mean hearing threshold for all frequencies with the largest increase observed at 3000 Hz with a 3.7 dB increase that was statistically significant. The mean hearing threshold remained almost similar at 4000 Hz and 6000 Hz with only a minimal 0.4 dB and 0.2 dB increase after three months post-intervention. The control group showed a reduction in mean hearing threshold after three months for all frequencies except 6000 Hz and 8000 Hz with the largest reduction seen at 500 Hz with a 3.5 dB reduction and found to be statistically significant ($p<0.05$). However the mean hearing threshold remained almost similar at 3, 4 and 8 kHz after three months. As for the intergroup mean difference, negative values were observed at all frequencies except 6000 Hz (1.08) but was not statistically significant.

Table 4.22: Right ear hearing threshold level changes of participants after three months

Frequency (Hz)	Intervention group (n=58)			Control group (n=96)			Intergroup	
	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Intragroup mean difference (SD)	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Intragroup mean difference (SD)	Intergroup mean difference (95% CI)	p value
500	22.6#(8.1)	26.2#(18.1)	3.6 (17.3)	15.6##(6.1)	12.1##(8.4)	-3.5*(9.4)	-7.15 (-11.92, -2.38)	0.004
1000	20.3(7.8)	21.8(16.7)	1.5(14.4)	15.1(6.9)	12.0(8.7)	-3.0*(9.2)	-4.49 (-8.24, -0.73)	0.019
2000	22.3(12.4)	23.6(19.1)	1.3(12.6)	13.9(8.2)	11.5(8.7)	-2.3*(8.7)	-3.64 (-7.04, -0.24)	0.036
3000	23.7(13.8)	27.4(20.4)	3.7*(12.7)	13.9(7.6)	13.0(10.4)	-0.8(10.0)	-4.55 (-8.20, -0.90)	0.015
4000	25.4^(15.7)	25.8^(22.4)	0.4(16.2)	16.7(10.7)	16.0(14.4)	-0.7(11.3)	-1.12 (-5.53, -3.30)	0.618
6000	22.9(21.5)	23.1(26.0)	0.2(17.0)	17.8(11.0)	19.0(15.5)	1.3(12.3)	1.08 (-3.60, 5.75)	0.650
8000	13.5^(22.2)	16.1^(24.4)	2.6(19.3)	14.3(13.5)	14.3(16.6)	0(12.5)	-2.63 (-7.70, 2.44)	0.307

*statistically significant intragroup mean difference ($p<0.05$); # n=43; ## n=79; ^ n=57

Intragroup mean difference = mean post-intervention – mean pre-intervention

Intergroup mean difference = mean difference control group – mean difference intervention group

Figure 4.17 shows the trend in changes of hearing threshold level for the left ear in the intervention and control group after three months. For the left ear, both intervention and control groups showed a reduction in hearing threshold level for all frequencies after three months. However the intervention group showed an increase of hearing threshold levels three months post-intervention for the frequencies 500 Hz and 8000 Hz. The largest reduction in hearing threshold post-intervention was observed at 6000 Hz (5.4 dB) for the intervention group and 500 Hz (3.5 dB) for the control group.

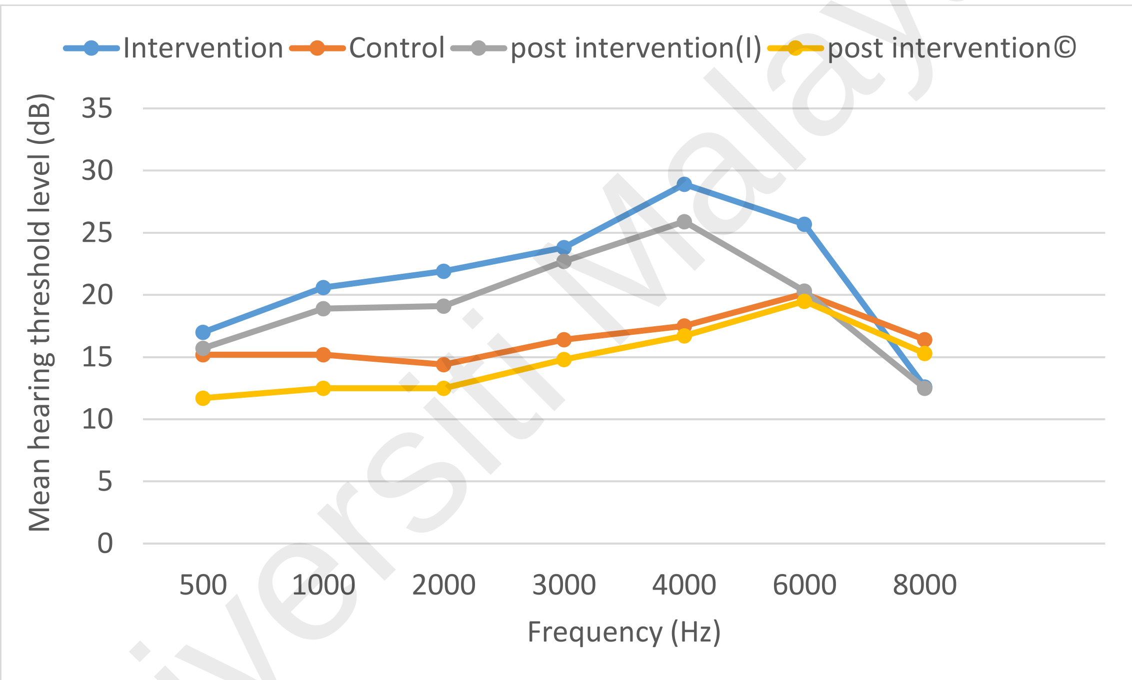


Figure 4.17: Changes in mean hearing threshold level for the left ear post intervention in both groups

Figure 4.18 shows the trend in changes of hearing threshold level for the right ear in both groups after three months. The intervention group showed a trend of higher hearing threshold level at all frequencies three months post-intervention mainly involving the lower frequencies (500, 1000, 2000 and 3000 Hz). Meanwhile the control group showed a reduction in hearing threshold levels after three months for all frequencies except 6000 Hz. The level of hearing threshold remained similar after three months at 8000 Hz for the control group.

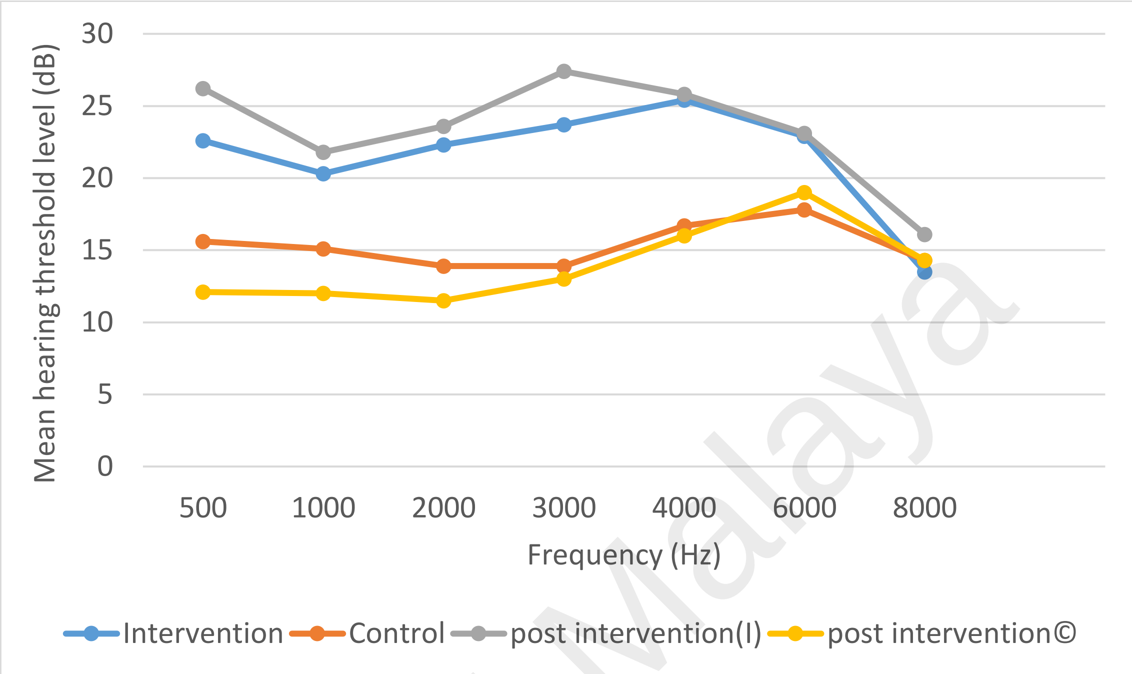


Figure 4.18: Changes in mean hearing threshold level for the right ear post intervention in both groups

4.6.2 Standard Threshold Shift (STS) after three months of intervention

The standard threshold shift (STS) was calculated at three months for both intervention and control groups using the pre-intervention (0 month) audiometry results as the baseline audiometry. The intervention group showed a lower proportion of participants with standard threshold shift (STS) in bilateral ear as compared to the control group with only 1.7% (left ear) and 8.8% (right ear) as shown in Table 4.23. All findings were statistically not significant.

Table 4.23: Proportion of participants with Standard Threshold Shift (STS) for bilateral ear after three months

	All N (%)	Intervention N (%)	Control N (%)	p-value
Left ear				
Normal	145 (94.2)	57 (98.3)	88 (91.7)	0.154
STS	9 (5.8)	1 (1.7)	8 (8.3)	
Right ear				
Normal	139 (90.8)	52 (91.2)	87 (90.6)	1.000
STS	14 (9.2)	5 (8.8)	9 (9.4)	

STS = Standard Threshold Shift

Table 4.24 shows the adjusted p-value after accounting for clustering effects due to the cluster design of this study. Adjustments to the chi-square test value was calculated by dividing the chi-squared value with design effect and subsequently the adjusted p-value was obtained by referring to the chi-square table (Campbell et al., 2000). The adjusted p-value for STS ranged from 0.10-0.15 for the left ear and 0.90-0.95 for the right ear. The adjusted p-values still remain statistically not significant (p>0.05).

Table 4.24: Standard Threshold Shift (STS) for bilateral ear after adjusting for cluster effect

	Design effect	*df*	X^2	p-value	Adjusted X^2	Adjusted p-value
Left ear	1.19	1	2.870	0.154	2.412	0.10 - 0.15
Right ear	1.19	1	0.016	1.000	0.013	0.90 - 0.95

df = Degrees of freedom; X^2 = Pearson Chi-Square

4.6.3 Changes in mean hearing threshold level at 2, 3 and 4 kHz after three months

The mean hearing threshold of each participant for three frequencies (2000, 3000 and 4000 Hz) was calculated and the overall changes in mean after three months was observed as shown in Table 4.25. For the left ear, both intervention and control groups showed an almost similar reduction in mean hearing threshold for these frequencies after three months with a reduction of 1.5 dB (intervention) and 1.4 dB (control) respectively. Meanwhile for the right ear, the intervention group showed a significant increase of 23.3 dB in mean hearing threshold for these frequencies after three months. As for the comparison in changes of mean hearing threshold between intervention and control group, a negative value indicates a greater improvement in mean hearing threshold in the control group as compared to the intervention group. The intervention group showed greater reduction in mean hearing threshold for the left ear (0.06 dB) in comparison to the control group but was not statistically significant.

Table 4.25: Changes in mean hearing threshold level at 2, 3 and 4 kHz after three months

	Intervention group (n=58)			Control group (n=96)			Intergroup	
	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Intragroup mean difference (SD)	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Intragroup mean difference (SD)	Intergroup mean difference (95% CI)	p value
Left ear	24.9 (11.4)	23.4 (12.7)	-1.5 (6.0)	16.1 (8.6)	14.7 (12.1)	-1.4 (8.7)	0.06 (-2.50, 2.62)	0.964
Right ear	23.6 (13.1)^	47.0 (30.2)^	23.3 (28.4)*	14.8 (7.9)	13.5 (10.1)	-1.3 (8.8)	-24.62 (-30.79, -18.45)	p<0.001

*statistically significant intragroup mean difference (p<0.05), ^n=57
Intragroup mean difference = mean post-intervention – mean pre-intervention
Intergroup mean difference = mean difference control group – mean difference intervention group

Table 4.26 below shows the adjusted p-value for changes in mean hearing threshold levels at 2, 3 and 4 kHz after accounting for clustering effects. All adjusted p-values were computed using the Social Science Statistics (2019) calculator made available at https://www.socscistatistics.com/pvalues/fdistribution.aspx. The adjusted p-value for changes in mean hearing threshold level for these three frequencies were 0.963 (left ear) and p<0.001 (right ear). The adjusted p-values still remain statistically significant (p<0.05) for the right ear only.

Table 4.26: Changes in mean hearing threshold level at 2, 3 and 4 kHz after adjusting for cluster effect

	Design effect	*df*	*t*	p-value	Adjusted *t*	Adjusted p-value
Left ear	1.19	152	0.046	0.964	0.042	0.963
Right ear	1.19	151	-7.887	p<0.001	-6.139	p<0.001

df = Degrees of freedom; *t* = T test score

4.6.4 Hearing Impairment changes after three months of intervention

Table 4.27 shows changes in proportion of participants with hearing impairment for bilateral ear in both groups after three months. The intervention group showed a 0.5% reduction in proportion of participants with hearing impairment for the left ear. Similar trends were observed in the control group but with only a 0.2% reduction. However, this result was statistically not significant. Meanwhile for the right ear, the proportion of participants with hearing impairment seem to increase in both groups after three months with a larger increase in proportion observed in the intervention group (8.8%) and it is statistically significant.

Table 4.27: Changes in proportion of participants with hearing impairment for bilateral ear after three months

	Pre-intervention			Post-intervention		
	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value
Left ear						
Normal	37 (82.2)	86 (91.5)		48 (82.8)	88 (91.7)	
Hearing impairment	8 (17.7)	8 (8.5)	0.154	10 (17.2)	8 (8.3)	0.121
Right ear						
Normal	35 (77.8)	89 (94.7)		40 (69.0)	90 (93.8)	
Hearing impairment	10 (22.2)	5 (5.3)	0.006	18 (31.0)	6 (6.2)	p<0.001

Hearing Impairment = average hearing threshold level at 500, 1000, 2000 and 3000 Hz which is shifted by 25 dB or more

Table 4.28 below shows the adjusted p-value for hearing impairment after accounting for clustering effects. The adjusted p-value for hearing impairment in the left ear three months post-intervention ranged from 0.10-0.15 and is statistically not significant. Meanwhile, the adjusted p-value for the right ear also remained similar with a statistically significant value ($p < 0.001$).

Table 4.28: Hearing impairment three months post-intervention for bilateral ear after adjusting for cluster effect

	Design effect	*df*	X^2	p-value	Adjusted X^2	Adjusted p-value
Left ear	1.19	1	2.780	0.121	2.336	0.10 - 0.15
Right ear	1.19	1	16.882	p<0.001	14.187	p<0.001

df = Degrees of freedom; X^2 = Pearson Chi-Square

4.6.5 Changes in mean hearing threshold level at 0.5, 1, 2, and 3 kHz after three months

The mean hearing threshold of each participant for four frequencies (500, 1000, 2000, and 3000 Hz) were calculated and the overall changes in mean after three months was observed as shown in Table 4.29. For the left ear, both intervention and control groups showed a reduction in mean hearing threshold for these frequencies after three months of intervention. The mean hearing threshold level was reduced by 1.4 dB and 2.6 dB ($p<0.05$) three months post-intervention in the intervention and control group respectively. Meanwhile for the right ear, the intervention group did not show any reduction in mean hearing threshold for these frequencies. The control group showed a reduction of 2.6 dB after three months with statistical significance. As for the intergroup mean differences, a negative value indicates a greater improvement in the control group as compared to the intervention group. The control group showed greater improvement in mean hearing threshold for both ears in comparison to the intervention group with the most improvement observed in the right ear ($p<0.05$).

Table 4.29: Changes in mean hearing threshold level at 0.5, 1, 2 and 3 kHz after three months

	Intervention group (n=43)			Control group (n=79)			Intergroup	
	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Intragroup mean difference (SD)	Pre-intervention Mean (SD)	Post-intervention Mean (SD)	Intragroup mean difference (SD)	Intergroup mean difference (95% CI)	p-value
Left ear	20.8 (7.4)	19.4 (11.1)	-1.4 (6.5)	15.0 (7.4)	12.4 (9.8)	-2.6 (7.8)*	-1.21 (-3.97, 1.55)	0.387
Right ear	22.1 (9.6)	25.3 (19.5)	3.2 (14.6)	14.1 (6.4)	11.6 (8.2)	-2.6 (8.2)*	-5.80 (-9.88, -1.71)	0.006

*statistically significant intragroup mean difference ($p<0.05$)
Intragroup mean difference = mean post-intervention – mean pre-intervention
Intergroup mean difference = mean difference control group – mean difference intervention group

Table 4.30 shows the adjusted p-value for changes in mean hearing threshold level at 0.5, 1, 2, and 3 kHz after accounting for clustering effects. All adjusted p-values were computed using the Social Science Statistics (2019) calculator made available at https://www.socscistatistics.com/pvalues/fdistribution.aspx. The adjusted p-value for changes in mean hearing threshold level for these four frequencies were 0.428 (left ear) and 0.011 (right ear). The adjusted p-values still remain statistically significant ($p<0.05$) for the right ear only.

Table 4.30: Changes in mean hearing threshold level at 0.5, 1, 2 and 3 kHz after adjusting for cluster effect

	Design effect	*df*	*t*	p-value	Adjusted *t*	Adjusted p-value
Left ear	1.19	120	-0.868	0.387	-0.796	0.428
Right ear	1.19	120	-2.811	0.006	-2.577	0.011

df = Degrees of freedom; *t* = T test score

4.6.6 Hearing Loss changes after three months of intervention

The proportion of participants with hearing loss in both groups for all seven frequencies (500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz) is shown in Table 4.31 below. For the left ear at low frequencies (500, 1000, 2000 and 3000 Hz), the intervention group showed a reduction in proportion of participants with hearing loss after three months of intervention at 1000 Hz (1.4% reduction) and 3000 Hz (2.4% reduction). Similar trends were observed at higher frequencies (4000, 6000 and 8000 Hz) and the largest reduction in proportion of participants in the intervention group with hearing loss after three months of intervention was seen at 4000 Hz with a 7.3% reduction. The control group showed a significant increase in proportion of participants with hearing loss in the left ear after three months at 8000 Hz with a 6.8% increase, while the intervention group showed a reduction in proportion from 22% (pre-intervention) to 17.2% (post-intervention).

Meanwhile for the right ear, the intervention group showed an increase in proportion of participants with hearing loss after three months of intervention at all low frequencies except 2000 Hz in which there was a 1.2% reduction. At high frequencies, there was a reduction in proportion of participants from the intervention group with right ear hearing loss at all three frequencies (4000, 6000 and 8000 Hz) except 8000 Hz with the largest reduction of 6.4% post-intervention observed at 4000 Hz.

Table 4.31: Changes in proportion of participants with hearing loss for bilateral ear after three months

Frequency	Pre-intervention						Post-intervention					
	Left ear			Right ear			Left ear			Right ear		
	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value
500 Hz												
Normal	42 (93.3)	93 (97.9)		37 (82.2)	91 (95.8)		48 (82.8)	91 (94.8)		38 (65.5)	93 (96.9)	
Hearing Loss	3 (6.7)	2 (2.1)	0.328	8 (17.8)	4 (4.2)	0.019	10 (17.2)	5 (5.2)	0.023	20 (34.5)	3 (3.1)	p<0.001
1000 Hz												
Normal	53 (88.3)	118 (95.9)		52 (86.7)	120 (97.6)		52 (89.7)	93 (96.9)		49 (84.5)	95 (99.0)	
Hearing Loss	7 (11.7)	5 (4.1)	0.062	8 (13.3)	3 (2.4)	0.006	6 (10.3)	3 (3.1)	0.082	9 (15.5)	1 (1.0)	0.001
2000 Hz												
Normal	50 (83.3)	117 (95.1)		50 (83.3)	118 (95.9)		48 (82.8)	90 (93.8)		49 (84.5)	94 (97.9)	
Hearing Loss	10 (16.7)	6 (4.9)	0.012	10 (16.7)	5 (4.1)	0.007	10 (17.2)	6 (6.2)	0.053	9 (15.5)	2 (2.1)	0.003
3000 Hz												
Normal	43 (71.7)	111 (91.0)		47 (78.3)	115 (94.3)		43 (74.1)	87 (90.6)		41 (70.7)	89 (92.7)	
Hearing Loss	17 (28.3)	11 (9.0)	0.002	13 (21.7)	7 (5.7)	0.002	15 (25.9)	9 (9.4)	0.011	17 (29.3)	7 (7.3)	p<0.001
4000 Hz												
Normal	37 (61.7)	104 (84.6)		43 (72.9)	111 (90.2)		40 (69.0)	79 (82.3)		46 (79.3)	85 (88.5)	

'Table 4.31, continued'

Frequency	Pre-intervention						Post-intervention					
	Left ear			Right ear			Left ear			Right ear		
	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value
Hearing Loss	23 (38.3)	19 (15.4)	0.001	16 (27.1)	12 (9.8)	0.004	18 (31.0)	17 (17.7)	0.074	12 (20.7)	11 (11.5)	0.161
6000 Hz												
Normal	40 (66.7)	103 (84.4)		43 (71.7)	106 (86.9)		40 (69.0)	78 (81.2)		43 (74.1)	76 (79.2)	
Hearing Loss	20 (33.3)	19 (15.6)	0.008	17 (28.3)	16 (13.1)	0.015	18 (31.0)	18 (18.8)	0.115	15 (25.9)	20 (20.8)	0.552
8000 Hz												
Normal	46 (78.0)	107 (87.0)		49 (83.1)	110 (89.4)		48 (82.8)	77 (80.2)		47 (81.0)	81 (84.4)	
Hearing Loss	13 (22.0)	16 (13.0)	0.133	10 (16.9)	13 (10.6)	0.240	10 (17.2)	19 (19.8)	0.832	11 (19.0)	15 (15.6)	0.659

Hearing Loss = average hearing threshold level at 500, 1000, 2000 and 3000 Hz which is shifted by 25 dB or more

The adjusted p-value for hearing loss among participants after accounting for clustering effects is shown in Table 4.32. The adjusted p-values were found to be statistically significant for the frequencies of 500, 2000 and 3000 Hz for the left ear which were similar to the unadjusted p-values. Meanwhile for the right ear, the adjusted p-values were statistically significant at all frequencies except 4000, 6000 and 8000 Hz and were similar to the unadjusted p-values.

Table 4.32: Hearing loss three months post-intervention for bilateral ear after adjusting for cluster effect

Frequency (Hz)	Left ear						Right ear					
	Design effect	*df*	X^2	p-value	Adjusted X^2	Adjusted p-value	Design effect	*df*	X^2	p-value	Adjusted X^2	Adjusted p-value
500	1.19	1	5.955	0.023	5.004	0.025 - 0.05	1.19	1	23.516	$p<0.001$	23.516	$p<0.001$
1000	1.19	1	3.425	0.082	2.878	0.05 - 0.10	1.19	1	12.478	0.001	10.486	0.001 - 0.002
2000	1.19	1	4.692	0.053	3.943	0.025 - 0.05	1.19	1	9.838	0.003	8.267	0.001 - 0.005
3000	1.19	1	7.471	0.011	6.278	0.01 - 0.025	1.19	1	13.324	$p<0.001$	11.197	$p<0.001$
4000	1.19	1	3.656	0.074	3.072	0.05 - 0.10	1.19	1	2.425	0.161	2.038	0.15 - 0.20
6000	1.19	1	3.046	0.115	2.560	0.10 - 0.15	1.19	1	0.521	0.552	0.438	0.10 - 0.90
8000	1.19	1	0.154	0.832	0.129	0.10 - 0.90	1.19	1	0.288	0.659	0.242	0.10 - 0.90

df = Degrees of freedom; X^2 = Pearson Chi-Square

4.6.7 Changes in knowledge, attitude and practice towards noise-induced hearing loss (NIHL)

Changes in knowledge, attitude and practice score towards noise-induced hearing loss (NIHL) was measured at one month and three months post-intervention. Table 4.33 shows changes in the percentage of knowledge, attitude and practice scores towards noise-induced hearing loss (NIHL) after one month of intervention in both intervention and control groups. The intervention group showed an increase in all three domains (knowledge, attitude and practice) after one month of intervention with an increment of 2.2% for knowledge, 1.6% for attitude and 0.9% for practice score. The control group also showed improvement in scores for all three domains after one month with the largest increment of 2.5% observed in the knowledge score. However, all results were statistically not significant.

In the analysis between intervention and control groups (intergroup), a negative mean difference score indicates a greater improvement in the intervention group as compared to the control group. Both intervention and control groups showed increase in mean scores for all three domains (knowledge, attitude and practice) after one month but a larger improvement was seen in the intervention group for the attitude and practice domain in comparison to the control group. For the practice domain, the intergroup mean difference was 0.35% with 95% CI of -5.2 to 4.5. The greatest improvement was seen in attitude domain where the intergroup mean difference was 0.9% (95% CI -4.1, 2.3). All results were statistically not significant.

Table 4.33: Changes in percentage knowledge, attitude and practice scores towards noise-induced hearing loss (NIHL) after one month

	Intervention group				Control group				Intergroup	
	Pre-intervention Mean (SD)	1 month post-intervention Mean (SD)	Intragroup mean difference (SD)	p value	Pre-intervention Mean (SD)	1 month post-intervention Mean (SD)	Intragroup mean difference (SD)	p value	Intergroup mean difference (95% CI)	p value
Knowledge	77.8 (10.7)	80.0 (12.3)	2.2 (12.6)	0.178	73.5 (11.7)	75.9 (10.9)	2.5 (14.3)	0.069	0.25 (-4.1,4.6)	0.910
Attitude	75.1 (9.9)	76.6 (9.8)	1.6 (10.1)	0.229	70.7 (10.9)	73.7 (10.3)	0.7 (10.1)	0.457	-0.9 (-4.1,2.3)	0.588
Practice	62.9 (16.6)	63.8 (15.5)	0.9 (15.7)	0.644	71.2 (14.3)	71.0 (13.4)	0.6 (15.1)	0.678	-0.35 (-5.2,4.5)	0.885

Intragroup mean difference = mean post-intervention – mean pre-intervention
Intergroup mean difference = mean difference control group – mean difference intervention group

Table 4.34 shows changes in the percentage knowledge, attitude and practice score towards noise-induced hearing loss (NIHL) after three months in both intervention and control groups. Both intervention and control groups showed a reduction in knowledge scores after three months with a reduction of 0.6 and 1.1 respectively. The intervention group showed an increase in both attitude and practice scores by 3.5 and 1.4 respectively after three months of intervention with statistically significant findings in the attitude domain. However, the control group showed a marked reduction in mean practice score from 71.2 to 66.7 after three months. All other findings were statistically not significant.

In comparison between the intervention and control groups, a negative mean difference score was observed in all three domains (knowledge, attitude and practice) indicating a greater improvement in the intervention group compared to the control group with the greatest improvement seen in the practice domain where the intergroup mean difference was -4.2 (95% CI -9.1, 0.7). For the knowledge and attitude domains, the intergroup mean difference was -0.6 (95% CI -5.0, 3.9) and -1.5 (95% CI -4.9, 1.9). The mean difference between the intervention and control groups was statistically not significant for all three domains.

Table 4.34: Changes in percentage knowledge, attitude and practice scores towards noise-induced hearing loss (NIHL) after three months

	Intervention group				Control group				Intergroup	
	Pre-intervention Mean (SD)	3 months post-intervention Mean (SD)	Mean Difference (SD)	p value	Pre-intervention Mean (SD)	3 months post-intervention Mean (SD)	Mean Difference (SD)	p value	Intergroup mean difference (95% CI)	p value
Knowledge	77.8 (10.7)	77.3 (11.8)	-0.6 (11.8)	0.713	73.5 (11.7)	72.2 (12.0)	-1.1 (14.6)	0.449	-0.6 (-5.0,3.9)	0.807
Attitude	75.1 (9.9)	78.2 (9.9)	3.5 (10.4)	0.011	70.7 (10.9)	74.0 (10.6)	1.3 (10.0)	0.141	-1.5 (-4.9,1.9)	0.378
Practice	62.9 (16.6)	63.6 (16.3)	1.4 (14.4)	0.441	71.2 (14.3)	66.7 (14.3)	-2.3 (14.6)	0.080	-4.2 (-9.1,0.7)	0.092

Intragroup mean difference = mean post-intervention – mean pre-intervention
Intergroup mean difference = mean difference control group – mean difference intervention group

Table 4.35 shows the scores for each domain (knowledge, attitude and practice) after being categorised according to satisfactory (≥75%) and unsatisfactory (<75%) scores. After one month of intervention, the proportion of intervention group participants with satisfactory scores for the knowledge domain remains unchanged at 71.7% while the proportion in the control group increased by 8.7%. Similar trends were observed in the intervention group for the attitude and practice domains with a reduction of 5% and 1.7% respectively after one month of intervention.

Meanwhile, three months post-intervention, both intervention and control groups showed a 7.7% – 7.9% reduction in proportion of participants with satisfactory scores for the knowledge domain. As for the attitude domain, a 0.3% increase in proportion of satisfactory scores was observed in the intervention group while the control group showed a 0.3% reduction in proportion of participants with satisfactory scores. For the practice domain, both groups displayed similar trends as found in the knowledge domain with a reduction in proportion of participants with satisfactory scores in both groups. However, the control group (15%) showed a larger reduction in proportion of participants with satisfactory scores after three months as compared to the intervention group (4.3%). All results were statistically not significant.

Table 4.35: Changes in proportion of satisfactory and unsatisfactory knowledge, attitude and practice scores towards noise-induced hearing loss (NIHL) after one month and three months

	Pre-intervention			One month post-intervention			Three months post-intervention		
	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value	Intervention N (%)	Control N (%)	p-value
Percentage total knowledge score									
Unsatisfactory	17 (28.3)	52 (42.3)		17 (28.3)	38 (33.6)	0.498	21 (36.2)	48 (50.0)	0.132
Satisfactory	43 (71.7)	71 (57.7)	0.076	43 (71.7)	75 (66.4)		37 (63.8)	48 (50.0)	
Percentage total attitude score									
Unsatisfactory	25 (41.7)	65 (52.8)		28 (46.7)	55 (48.7)	0.873	24 (41.4)	51 (53.1)	0.185
Satisfactory	35 (58.3)	58 (47.2)	0.161	32 (53.3)	58 (51.3)		34 (58.6)	45 (46.9)	
Percentage total practice score									
Unsatisfactory	45 (75)	75 (61.0)		46 (76.7)	67 (59.3)	0.029	46 (79.3)	73 (76.0)	0.695
Satisfactory	15 (25)	48 (39.0)	0.069	14 (23.3)	46 (40.7)		12 (20.7)	23 (24.0)	

CHAPTER 5: DISCUSSION

The objectives of this study are divided into two phases:

a) Phase 1: Development the of the Hearing Conservation Program (HCP)

b) Phase 2: Implementation and evaluation of the Hearing Conservation Program (HCP)

The second phase involves determining the effectiveness of the HCP in preventing or reducing audiometric threshold changes among vector control workers.

Vector control workers work in a noisy environment mainly during fogging activity. This puts them at risk of developing hearing impairment or hearing loss due to exposure to excessive noise. The noise exposure monitoring showed that vector control workers were exposed to noise levels well above 85 dB (see section 5.1 for further details). It is important for noise-induced hearing loss prevention steps to be taken to ensure workers hearing are protected esepecially since NIHL is irreversible and results in permanent damage to hearing. Hence, there is a need for an effective and comprehensive Hearing Conservation Progrm (HCP) to be implemented specifically for vector control workers (Azizi, 2010).

The development phase of the HCP involved 3 key domains: a systematic literature review; comparing local and international guidelines on hearing conservation programs; interviews with key stakeholders. The systematic review identified 3 key strategies for NIHL prevention which is leadership, one-off training and combination of multiple strategies (multifactorial intervention). This HCP is a form of multifactorial intervention as it consists of leadership roles, exposure monitoring, hazard communication, audiometry surveillance and a training and education program. The HCP includes the following 8 elements: safety and health policy, noise monitoring, noise control, provision of hearing protection, training and education programme, audiometry testing, record keeping, monitoring and evaluation. This is similar to the standards recommended by OSHA for a successful HCP which consists of 7 elements excluding monitoring and evaluation of program (Rogers et al., 2009). Key stakeholders in the field of occupational health from within the country were engaged at the beginning of this study during the development phase. One of the key stakeholders engaged during this phase was the Ministry of Health (MOH) involving district health offices, state health departments and state occupational and environmental health units. Field visits with vector control workers and the safety and health committee provided valuable insight on issues faced by vector control workers during fogging activity. One of the key findings was poor adherence to use of hearing protection devices (HPD) due to difficulty to communicate while using HPDs. A systematic review reported similar findings as key barriers and suggested superiors or supervisors to be role models to workers to increase adherence to HPD usage (Laird et al., 2012). Interviews with representatives from the Department of Occupational Safety and Health (DOSH) mainly from the occupational health unit proved valuable especially when reviwing current local guidelines as well as regulations and acts related to safety and health. A major difference identified between the local Noise Regulation 1989 and international guidelines was the permissible exposure limit (PEL). The local regulations stipulated the PEL as 90 dB while regulations from other developed countries such as U.S.A., Canada and United Kingdom have their PEL set at 85 dB with a 3 dB exchange rate (Factory and Machineries Act, 1989; US Department of Labor, 2013). Engagement with the key stakeholders concluded that the PEL to be adhered to was based on local standards. Interagency collaboration is vital to ensure success of the program especially when it involves multiple stakeholders.

The implementation of this program at the district health offices from the intervention group required involved a multidisciplinary collaboration between district health officers, HCP coordinators, managers and vector control workers. The involvement of top management was needed for an effective HCP. Hearing Conservation Program (HCP) coordinators and managers were briefed on the purpose and implementation strategy of the HCP. Their roles and responsibilities were also clearly explained during the training and education program. Supervisors and managers need to have basic knowledge on all 8 elements of the HCP since they are directly involved with the vector control workers (Rogers et al., 2009).

5.1 Barriers to implementation of Hearing Conservation Program (HCP)

Developing a policy or program is merely the initial step, for it to be successful and achieve the desired outcomes or objectives highly depends on how well it is implemented and monitored. Identifying challenges or barriers to implementation of any program is a form of program evaluation and provides vital information to the program coordinators for improvement in the future (Implementation Barriers, 2014).

A Hearing Conservation Program (HCP) is a multicomponent program involving many key stakeholders and requires coordination and collaboration between parties responsible for implementation of the program. During the implementation phase of this study, one of the barriers identified was to involve all key stakeholders including district health officers, vector control workers, the safety and health committee and health clinics for audiometry testing. Most often there is a lack of coordination and collaboration between the health clinics and district health office including the safety and health committee, hence they may not be receptive to issues faced by workers on the field during fogging activity. There is also a lack of feedback from the health clinics to the district health offices on findings from their hearing surveillance of vector control workers. One of the measures taken to address this issue is to ensure the roles and responsibilities of all stakeholders including the employer (hearing conservation program coordinator) and employee (vector control workers) are clearly defined. A copy of the Hearing Conservation Program (HCP) module (see Appendix W) was given to all participating district health offices from the intervention group. This module consists of an introduction, objectives and steps to implementation that will serve as a guide to effective implementation of this program.

According to the hierarchy of control, engineering controls should be given priority followed by administrative controls and personal protective equipment. However, due to limited budgets and financial constraints within the Ministry of Health, it is difficult for the organization to administer engineering controls such as replacing existing fogging machines with ones that are less noisy or attaching noise dampening devices to the fogging machines. Hence a more feasible approach using administrative controls such as periodic preventive maintenance was proposed.

During field visits with the vector control workers carrying out fogging activity prior to the implementation of this program, feedback regarding the use of hearing protection devices (ear muff) was obtained. Usage of ear muffs during fogging activity was one of the barriers identified as it causes discomfort due to sweat as well as difficulty in communication among vector control workers. Some vector control workers who were not directly involved in the fogging activity but were exposed to high noise levels such as drivers and supervisors preferred not to wear hearing protectors putting them at higher risk for noise-induced hearing loss. A systematic review of effective strategies in the prevention of noise induced hearing loss (NIHL) reported lack of usage of hearing protection devices among managers and supervisors as one of the key barriers to implementation of an effective intervention to prevent noise-induced hearing loss (NIHL) (Laird et al., 2012). To overcome these issues, especially among vector control workers who were indirecty involved in fogging activity but are still exposed to noise emitted by the fogging machines, a recommended minimum safe distance of 7 meters was suggested based on the noise mapping done. Hence workers not handling the fogging machine that maintain a minimum distance of 7 meters from any fogging machine need not use any hearing protection devices as the noise levels from this distance is well below 85 dB (A). For vector control workers handling the thermal fogging machine, hazard communication of noise exposure monitoring results during the training program was vital as many did not know the actual exposure levels to date. Often employees are not furnished with vital information particularly noise exposure monitoring findings resulting in poor understanding of the hazards they are exposed to at the workplace. Apart from that, information regarding effects of noise on health, legislative requirements and proper use and care of hearing protection devices was given to vector control workers during the training and education program. This information will act as a precursor for change in the vector control workers perceived benefits of action, perceived barriers to action and perceived self-efficacy which will ultimately result in cues to action or change in safety and health practice (Heydari & Khaorasan, 2014). In other words, it will result in increased use of hearing protection devices in a proper manner despite the issue of comfort as the vector control workers understand the hazard risk and benefits of complying with proper use and care of hearing protection devices.

As part of this Hearing Conservation Program (HCP), an annual evaluation and review is recommended. An evaluation form is used to gather feedback form the vector control workers as well as employers and findings can be integrated into subsequent action plans. Monitoring and evaluation is vital to track program implementation and outputs systematically while ensuring program objectives are achieved.

5.2 Baseline characteristics

The participants of this study were vector control workers from district health offices in the state of Perak, Malaysia. The majority of the participants were males of Malay ethnicity with an average age of 37.3 years. More than 60% of the participants received education up to secondary level. There was no significant difference between the two groups with regards to gender, age, level of education, average monthly household income and number of household members. However, significantly different sociodemographic characteristic in terms of ethnicity was observed between both groups.

5.2.1 Baseline occupational, noise exposure and lifestyle characteristics

The average duration of employment for all participants was 8.6 years and majority are employed as general workers and public health assistants. Similar findings in terms of job title of participants who are involved directly in fogging activity were reported in another study involving foggers (Institute of Public health, 2015). Both intervention and control group participants shared similar noise exposure characteristics in past occupational exposure to noise and living in noise residential area. The majority of participants did not live in a noisy residential area. However, a significant difference was observed between the groups in use of fogging machine with a higher proportion of participants in the control group using fogging machine as compared to the intervention group. This could be attributed to the more urban nature of the district health offices in the control group resulting in increased fogging activities due to the higher number of dengue prevalence. The majority of the participants were non-smokers while only 29.5% smoke and more than 90% denied engaging in activities that may increase the risk of hearing loss such as diving and using guns or explosives. This was consistent with the prevalence of current smokers among Malaysians aged 15 years and above that was reported as 22.8% in the National Health and Morbidity Survey (NHMS) 2015 of Malaysia (Institute of Public health, 2015). There was no reported use of ototoxic drugs among the participants.

5.2.2 Baseline medical condition

The majority of participants did not have any underlying medical conditions with only 13% suffering from non-communicable diseases (NCD) mainly diabetes mellitus and hypertension. According to the National Health and Morbidity Survey (NHMS) 2015, overall prevalence of diabetes mellitus and hypertension among adults 18 years and above in Malaysia is 17.5% and 33.1% respectively (Institute of Public health, 2015). For symptoms related to hearing, only 9.7% reported symptoms of tinnitus with 3.3% having been treated for related problems at least once before. Meanwhile, 7.8% of total participants reported some difficulty in listening. Estimates of population based tinnitus prevalence is still lacking in Malaysia but a study conducted in Australia reported a prevalence of tinnitus as 20.7% among adults aged 55 to 99 years of age (Kim et al., 2015). The higher prevalence can be explained by the older age group of the population studied as compared to the mean age of the participants in this study (37.3 years). Otherwise the baseline medical conditions characteristics were similar among participants from both groups.

5.3 Noise exposure level

Area monitoring results suggest that noise emitted from the thermal fogging machine ranged from 100 – 115 dB. Meanwhile the noise emitted from the ultra low volume (ULV) fogging machine is much lower and ranged from 85 to 91 dB. The personal noise exposure levels for workers handling the thermal fogging was above the action level of 85 dB (A) as stated in the Noise Regulation 1989 under the Factory and Machinery Act. The control group (93.1 dB) showed a higher personal noise exposure level for an 8-hour Time Weighted Average (TWA) compared to the intervention group (87.3 dB). This discrepancy could be due to the lack of periodic maintenance of the thermal fogging machine used in the control group. Another study conducted among vector control workers in Malaysia reported similar noise exposure levels of more than 90 dB (A) at a distance of 0.5 meter (Masilamani et al., 2014). On the other hand, personal monitoring results of workers handling the ultra low volume (ULV) fogging machine was well below the action level.

The noise mapping done for the thermal fogging machine indicated that noise levels fall below the action level or 85 dB(A) at a distance of 7 meters and above. This was introduced as a safe distance from a fogging machine, mainly the thermal fogging machine when not wearing any hearing protection devices. This was important as one of the barriers identified during the development of the Hearing Conservation Program (HCP) is that vector control workers not directly handling the fogging machine such as supervisors lack usage of hearing protection devices during fogging activity but are still exposed to excessive noise putting them at risk of hearing loss.

5.4 Process evaluation

In the field of public health mainly occupational health, interventions are targeted for populations at risk rather than individuals respectively. In this interventional study the population at risk or target population are vector control workers exposed to excessive noise during fogging activities. Often great importance and caution is given to the internal validity of an interventional research when determining effect estimates of an intervention.

The researcher managed to achieve the required sample size with a total of 183 eligible participants being recruited at baseline accounting for a predicted attrition rate of 20%. Follow-up of participants were done at one month post-intervention and baseline measurements as well as three months post-intervention. The follow-up rate for both intervention and control group were above 90% at 1 month post-intervention with the intervention group achieving a 100% response rate. Meanwhile during the the final follow-up at 3 months post-intervention, the follow-up rate achieved was well above 80% for each group respectively. This is an acceptable response rate with studies reporting 75% as an acceptable response rate although determining an acceptable response rate depends on various factors such as the size of the target population studied and intention of use of findings from the study (Nulty, 2008). A high response rate is also needed to prevent nonresponse bias that will affect the reliability and validity of the study findings. A low response rate of 30% is said to result in a nonresponse bias of 70% or lower (Fincham, 2008). Loss to follow-up rate is another key indicator and is a form of selection bias particularly in cohort studies. Although it is inevitable in most longlitudinal studies and results in loss of study statistical power, it is important to keep loss to follow-up rate as low as possible. The loss to follow-up rate in this study is 3.3% for the intervention group and 22% in the control group. This is a fairly good loss to follow-up rate with studies having reported less than 30% as an acceptable loss to follow-up rate and less than 5% leads to little bias (Kristman, Manno, & Côté, 2003; Sartipy, 2017). The main reasons for loss to follow-up were due to workers being transferred to different work units or district health offices as well as work absenteeism during outcome measurements. A couple of steps were taken to keep the loss to follow-up rate to a minimum such as use of an appointment card for audiometry testing and contacting superviors prior to follow-up to serve as a reminder.

In relation to nonresponse, often studies relying on volunteer samples in particular may result in lack of representativeness of the target population in which the study findings will be generalized. Hence, certain demographic and noise exposure characteristics of respondents and non-respondents were compared to determine if any difference were observed and to avoid inaccurate conclusions. Non-respondents were vector control workers from district health offices in the state of Perak that shared similar characteristics with respondents. All compared indicators showed no significant difference. The demographic characteristics measured showed majority of the respondents and non-respondents being males of Malay ethnicity with a mean age of 35 to 37 years old. The education level was also similar between the respondents and non-respondents with the majority receiving secondary education and below. As for noise exposure characteristics, both respondents and non-respondents showed similar characteristics with majority having used a fogging machine and around 50% having previous occupational exposure to noise.

Another part of process evaluation involves assessing the attendance rate of participants of the intervention group to the training and education program that was conducted after baseline measurements were completed. Attendance of participants were only available for the intervention group as the control group did not receive any form of intervention during the study and only received the training program after the study was completed. The attendance rate of the participants from the intervention group was 100%. The high response rate achieved in this study is highly attributable to certain measures taken such as conducting the training and education programs in the respective district health offices so participants do not need to travel and take time off their work. Besides that, participants were also given an appointment card to serve as a reminder for their audiometry testing appointment date and time to ensure outcome measurements can be carried out for all participants.

5.5 Outcome evaluation

The outcomes evaluated in this study includes:

- Primary outcome: Audiometric hearing threshold changes
- Secondary outcome: Knowledge, attitude and practice towards noise-induced hearing loss (NIHL)

5.5.1 Effects of Hearing Conservation Program (HCP) on hearing threshold level

A marked improvement in hearing threshold level was observed three months post-intervention especially at higher frequencies despite the control group having a better baseline mean hearing threshold level in bilateral ear as compared to the intervention group. This may not be due to age-related changes since the mean age of participants in both intervention (37.7 years) and control group (36.6 years) are almost similar. It has been reported that in the early stages of noise-induced hearing loss (NIHL) the average hearing thresholds at the lower frequencies of 500, 1000, and 2000 Hz are better than the average thresholds at 3000, 4000, and 6000 Hz (Kirchner et al., 2012a). A study by Riga et al. (2010) emphasized the role of extended high frequency audiometry in early detection of noise-induced hearing loss with relation to employment duration. The findings from this study suggest that the frequencies of 12500, 14000 and 16000 Hz are first affected during the first decade of employment. Changes at 2000 and 4000 Hz were only observed during the second decade of employment and hearing threshold changes at lower frequencies (250, 500 and 1000 Hz) were observed after two decades of employment (Riga et al., 2010). The mean duration of employment of participants in both groups were below 10 years in this study hence causing hearing threshold changes to be less evident since the extended higher frequencies were not tested as a conventional audiometry was used in this study.

NIHL is a form of permanent irreversible sensorineural hearing loss. The use of standard threshold shift as an outcome to evaluate the effectiveness of the HCP in prevention of NIHL includes permanent threshold shift. The improvement in hearing threshold level observed in this study is possibly due to temporary threshold shift experienced by workers despite being asked to ensure a 14 hour silent period prior to audiometric testing. According to local regulations, Industry Code of Practice (ICOP) for Management of Occupational Noise Exposure and Hearing Conservation 2019, the presence of a temporary threshold shift is a risk indicator that the likelihood for NIHL to occur with continuous noise exposure (Malaysia, 2019).

Studies have suggested the use of audiometric database analysis (ADBA) for evaluating the effectiveness of hearing conservation programs and measuring Standard Threshold Shifts (STS) serves as a reliable early indicator for noise-induced hearing loss (Lane, Dobie, Crawford, & Morgan, 1985)(Adera, Gullickson, Wang, & Gardner, 1995)(Lane et al., 1985). However, the limitation of this method is a stringent criteria for analysis resulting in drastic reduction of sample size. Hence, it would not be appropriate to be applied to HCPs of small and medium-sized enterprises. In this study, mean hearing threshold shift changes were observed for all frequencies to evaluate the effectiveness of the Hearing Conservation Progrm (HCP). This method is similar to one of the recommended methods by the American National Standards Institute (ANSI) in which mean hearing threshold levels over time or threshold shifts (standard deviation of threshold shifts) were measured from individual audiometric frequencies (0.5, 1, 2, 3, 4, 6, and 8 kHz) and grouped frequency combinations (0.5-3 kHz and 2-4 kHz). This way, one is able to rule out systematic threshold shift due to variation in audiometric calibration. Hence, this method serves as a reliable early indicator of the Hearing Conservation Program (HCP) performance besides indirectly reflecting the audiometric testing program integrity (Simpson, Stewart, & Kaltenbach, 1994). There is also a risk of false positive threshold shifts during audiometric testing caused by various factors such as calibration errors, test-retest variability, absence of baseline audiogram and absence of detailed case-history information (Schlauch & Carney, 2010). Hence it is important to differentiate permanent threshold shifts (PTS) from temporary threshold shifts (TTS) as TTS it may directly inflate the mean hearing threshold for each frequency. To reduce the risk of TTS, participants were given clear instructions during audiometry testing and ambient noise was maintained at an acceptable level (Noise & Audiometric, 2006). An annual audiogram of individual workers may result in excessive audiometric variability which may translate to either poor audiometric testing methods or less effective hearing conservation programs. If audiometric testing methods are acceptable, then the excessive audiometric variability can be associated with the occurrence of temporary threshold shifts reflecting an inadequate or less effective hearing conservation program (Simpson et al., 1994). All audiometric booths used in this study were calibrated accordingly to reduce measurement errors and a standard definition of Standard Threshold Shift (STS) in accordance to local regulations (Noise Regulation 1989) was used during the period of this study to avoid discrepancy in reference levels. The proportion of participants with Standard Threshold Shift (STS) was relatively higher among the control group compared to the intervention group for bilateral ear indicating an effective Hearing Conservation Program (HCP). The analysis of grouped frequencies (2, 3 and 4 kHz) found the intervention group participants to have a better reduction in mean hearing threshold in the right ear for these frequencies as compared to the control group indicating an effective HCP. The variation in mean hearing threshold between the left and right ear for these frequencies could be explained by various factors such as age related hearing loss and occurrence of threshold shift in only one ear. Hence data on threshold shifts should be evaluated separately for each ear (US Department of Labor, 2013).

The changes in mean hearing threshold observed for both grouped frequencies (2-4 kHz and 0.5-3 kHz) showed positive dominant changes in the left ear as compared to the right ear. Despite NIHL being known for bilateral symmetrical hearing loss, this laterality in threshold shift or asymmetrical threshold shift observed is quite common and has been reported that up to 80% of audiometric shifts meeting the Occupational Safety and Health Administration (OSHA) standards were found to be unilateral (Simpson, McDonald, & Stewart, 1993).

This is mainly attributable to asymmetric individual baseline hearing threshold level and participants from the control group showed better average hearing threshold for each frequency in comparison to the intervention group. The better average hearing threshold observed among control group participants could be due to various factors such as varying individual susceptibility to age related hearing loss and noise damage as well as other non-occupational noise sources (power tools, attendance at sporting events, motor races, and loud concerts) (Franks, 2001; Royster, 2017).

An effective Hearing Conservation Program (HCP) is a comprehensive program equipped to protect the hearing of employees at risk of hearing impairment due to occupational noise exposures (US Department of Labor, 2002). It has been reported that a reduction in average hearing threshold by 1 dB per year over the initial four years to be an early indicator of an effective hearing conservation program (Simpson et al., 1994). A successful hearing conservation program mainly requires good interdisciplinary team work between employees, the hearing conservation program team, the safety and health committee and managers (Rogers et al., 2009).

At baseline the proportion of participants with hearing impairment for both intervention and control group is 11 % for either ear with 10 % of the total participants reporting symptoms of tinnitus. Tinnitus is a common condition affecting 10–15% of the population with less than 2% experiencing severe tinnitus symptoms with reduced quality of life (Schaette & McAlpine, 2011). The correlation of tinnitus and hearing loss has long been debated by researchers due to the many causes of tinnitus mainly due to insult to the cochlear resulting in abnormal neuronal activity in the central auditory pathways that can be perceived as tinnitus. Although chronic tinnitus has been associated with hearing impairment but it is still unknown if hearing loss causes tinnitus. The difficulty with deriving a temporal relationship between hearing loss and tinnitus is the fact that tinnitus is not present in patients suffering from hearing loss and not all patients suffering from tinnitus produce an abnormal audiogram (König, Schaette, Kempter, & Gross, 2006; Langguth, Kreuzer, Kleinjung, & De Ridder, 2013; Weisz, Hartmann, Dohrmann, Schlee, & Norena, n.d.). This can be attributed to the nature of the audiogram in which some forms of sensory input loss are not detected during audiometric testing. In this study, the symptoms of tinnitus were identified during otoscopic examination of participants prior to audiometric testing with many participants unaware of the condition and its causes. This lack of knowledge regarding tinnitus could be associated with the majority of participants only receiving up to secondary education or possibly unaware of such a condition. However, evidence suggests that reports of tinnitus during audiometric screening and ear examinations are useful in identifying workers at risk of developing permanent threshold shifts and could serve as an early indicator for noise-induced hearing loss (Griest & Bishop, 2018).

5.5.2 Effects of Hearing Conservation Program (HCP) on knowledge, attitude and practice towards noise-induced hearing loss (NIHL)

The secondary outcome measured at one month and three months post intervention shows that the intervention proved to be effective in improving knowledge, attitude and practice towards noise-induced hearing loss (NIHL). This improvement in practice was consistent with the findings from the study by Lusk et al. (1999) in which a theory-based intervention significantly increased use of hearing protection devices among construction workers (Lusk et al., 1999). Similar findings were reported by Seixas et al. (2011) where a multi-component intervention combining training and personal noise level indicators were effective in increasing hearing protection devices usage among construction workers (Seixas et al., 2011). In this study, part of the intervention includes a training and education program to increase awareness towards noise-induced hearing loss (NIHL) and improve hazard communication between employer and employee. Besides general information regarding noise-induced hearing loss (NIHL), noise exposure monitoring results were also shared with the participants during the training sessions providing them with better understanding of the hazard. All this information helped improve participants perceived susceptibility and severity which results in change in practice by enhancing cues to action and self-efficacy constructs as outlined in the Health Belief Model that is widely used to explain preventive health behaviour (Montano & Kasprzyk, 2008).

In this study, improvement in attitude and practice was greater at three months post-intervention as compared to one month post-intervention. The lack of improvement in knowledge, attitude and practice towards noise-induced hearing loss (NIHL) after one month of intervention could be attributed to recall bias since there was no assessment immediately after implementation of the intervention. This observed pattern could also be explained using the socio ecological model in which many factors determine the success and outcome of an occupational health intervention such as this Hearing Conservation Program (HCP). At an individual level, characteristics of each participant including knowledge, attitude, perception, self–efficacy and practice towards noise-indcued hearing loss (NIHL) varies accordingly as an independent variable in this study (Mcleroy, Bibeau, Steckler, & Glanz, 1988). Participants with a higher pre-existing knowledge, attitude and behaviour towards safelty and health practice concerning noise-induced hearing loss (NIHL) may influence the knowledge, attitude and practice outcome domains in this study. Besides that, from the socio ecological perspective, associated factors from the interpersonal and organizational level also play a vital role in determining the effect of HCP on knowledge, attitude and practice of workers towards NIHL. The organizational role in implementation and monitoring of an occupational health intervention is vital especially in this study where one of the components of the HCP includes safety and health training of workers. The frequency of safety and health training programs focusing on noise-induced hearing loss (NIHL) varies between each district as it is provided by the respective district health office. Studies have shown that safety and health training programs are effective in improving knowledge, attitude and practice of workers (Golden & Earp, 2012). Hence, more frequent training or workshop sessions need to be given to workers with a fair interval between training sessions to ensure better safety and health practices among workers. This training sessions targets changes at the interpersonal level of the socio ecological model mainly perception, attitude and behavior towards safety and health practices of workers towards NIHL especially in terms of proper usage and care of hearing protection devices (Golden & Earp, 2012). As observed in this study the control group participants showed a larger increase in mean score for the knowledge domain as compared to the intervention group one month post-intervention and this could be attributed to more safety and health training programs received by the participants in the control group prior to commencement of the study. In addition, the organizational role played by each district health office also affects the safety climate and workplace culture especially among urban and rural district health offices with urban populations having shown to have better knowledge and awareness towards particular diseases as compared to rural populations (Wei et al., 2010). Based on the geographical locations and characteristics of urbanization, the district health offices in the control group were made up mainly of workers from the urban population. Meanwhile, the intervention group participants were mostly from the rural population. The difference in characteristics of participants in the intervention and control group in terms of rural and urban explains the higher average practice scores among participants from the control group as compared to the intervention group before delivery of intervention. The larger improvement in the knowledge domain observed one month post-intervention in the control group compared to the intervention group may also be influenced by the fact that the control group participants were mainly made up of the rural population. The varying population characteristics (rural or urban) may also serve as a barrier to implementation of occupational health interventions including hearing conservation programs (Barnidge et al., 2013). However in terms of cultural demographics, they were fairly similar among the rural and urban population participants but the accessibility to healthcare services is better in the urban setting. At the policy level of the socio ecological model approach, all district health offices are adhering to a standard safety and health policy which is produced by the Ministry of Health for all healthcare facilities within the country. In summary, various factors determine the effectiveness of the Hearing Conservation Program (HCP) as explained by the socio ecological model approach above. All these factors need to be addressed in order to ensure the desired objective of the occupational health intervention is achieved and the organizational role is pivotal in the implementation and monitoring of a program in order for it to successful.

The training and education program provided in this study as part of the Hearing Conservation Program (HCP) is a form of behavioural intervention. Besides improving knowledge, attitude and practice one month and three months post-intervention, behavioural interventions are proven to improve self-perceived severity, susceptibility and benefits as explained by the health belief model (Glanz, Lewis, & Rimer, 2006). This is consistent with evidence from the literature suggesting a positive impact of training programs in improving knowledge, attitude and practice of workers (Bjerrum, Tewes, & Pedersen, 2012; Harrington & Walkers, 2004; Lahti et al., n.d.; Zhang et al., n.d.). The training and education program showed a marked effect in improving workers' attitude in terms of health seeking behaviour, preventive and risk taking attitude towards noise-induced hearing loss. In terms of practice, the workers showed changes in behavioural practice towards prevention of noise-induced hearing loss. One of the key reasons for these changes is including hazard communication in the training program, which includes noise exposure monitoring results, noise attenuation achieved with hearing protectors and effects of noise and health. This information will furnish the workers with the required information that will affect their perceived severity and susceptibility of NIHL as well as benefits of preventive measures and result in change in behavior in relation to safety and health practices. However, it is important that training programs be provided from time to time to workers and not as a one-time only intervention. This could be explained by the reduction in knowledge scores of workers observed at three months post-intervention. Continuous training is needed to ensure updating of existing knowledge as well as refreshing knowledge gained from previous training sessions. However, evidence on frequency of training sessions is still lacking. The type and method of how safety and health training is conducted also affects the outcome. Workers who are engaged and actively participate during training programs show better outcomes as compared to passive type training programs. In recent years, there has been development in methods of safety and health training programs from information-based to computer-based techniques and performance-based techniques or hands-on workshops (Burke et al., 2006). This shift from the usual passive methods towards more active methods is a result of increasing research looking into effective training methods as it has been recognized that passive methods seem to be less effective in recent years. The training program in this study involves individual participation of workers during the hands-on workshop in which each worker was required to practice the proper use and care of hearing protection devices as well as performing the fit-test. This method is more engaging and interactive besides allowing on-site assessment of workers' usage and care of hearing protection devices.

Most interventions generally give more emphasize on individually focused behavior change strategies especially when dealing with occupational health interventions, while neglecting the environmental factors that are associated with occupational diseases. A review by Verbeek et al. looking into effective occupational health interventions including hearing conservation programs proposed a model of primary preventive occupational health intervention that categorizes these interventions into three major classes mainly environmental, behavioural and clinical (Verbeek & Ivanov, 2013). In this model, all three components play a vital role in prevention of occupational noise-induced hearing loss and must be given equal importance. This is due to the fact that the hearing conservation program includes all three components to prevent noise-induced hearing loss. In this study, administrative controls such as periodic preventive maintenance of the fogging machine as well as a recommended safe distance can be categorized as environmental interventions to reduce the level of noise exposure. It is important that other measures of noise control were recommended in this hearing conservation program besides the usual behavioural interventions such as training to increase proper use and care of hearing protection devices which is rightly the lowest in the hierarchy of controls.

5.6 Strengths and limitations of the study

All research conducted comes with its own strength and weakness and it is important to understand them before interpreting the results or generalizing the findings. This section discusses the strengths and limitations of this study.

5.6.1 Strengths of study

The comprehensive Hearing Conservation Program (HCP) developed for this study in the first phase was based on many sources including a systematic review to ensure a high quality of evidence of effective interventions in prevention of noise-induced hearing loss (NIHL). The reporting of the systematic review was systematic and reproducible based on PRISMA guidelines. The intervention, including a training and education program was delivered by the researcher himself whom is also a registered occupational health doctor. The elements of the intervention in this study complies with local requirements mainly Noise Regulation 1989 and international guidelines for hearing conservation by the Occupational Safety and Health Administration of the U.S. Department of Labor (Occupational Safety and Health Administration, 2002).

In terms of evidence-based practice, the cluster randomized methodological design of this study provides the highest level of evidence especially in determining a causal relationship between an intervention and the desired outcome. Randomization reduces the risk of selection bias and facilitates blinding by masking the identity of the participants' groups from the outcome assessors. The risk of selection bias was also reduced by ensuring allocation concealment during group assignment of the district health offices. The sample size was calculated using findings from similar studies and were reported systematically according to CONSORT guidelines to ensure it meets ethical requirements and produce scientifically valid results. The sample size calculated was achieved with a low drop-out rate of 3.3% and 22% in the intervention and control group respectively. All outcomes including negative findings were reported in this study.

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Both primary and secondary outcomes were measured using validated and reliable instruments in both groups and analysis was done based on per-protocol principles which allows for estimation of the intervention effect under optimal conditions by excluding participants that violated the protocol. A high quality of evidence was also ensured with a follow-up rate of more than 85% at one month and three months.

The World Health Organization (WHO) has long advocated for an integrated approach to occupational health and primary care as part of achieving universal health coverage for all employees (WHO, 2012). During the implementation phase of the Hearing Conservation Program (HCP), audiometry testing was conducted at five primary care clinics strategically located in the state of Perak that were easily accessible by vector control workers. Besides that, information regarding the HCP was shared with nurses and occupational health doctors at the primary care clinics to ensure all stakeholders are involved and the program is implemented effectively. Even during the development phase of the Hearing Conservation Program (HCP), key stakeholders in the field of occupational health were engaged including the Ministry of Health and Department of Occupational Safety and Health (DOSH). It is important that all relevant stakeholders are involved during the development and implementation phases and given adequate information especially objectives and implementation process of the program.

5.6.2 Limitations of study

Despite measures in study methodological design taken to reduce bias, complete elimination of bias is impractical especially from certain sources. In this study, only single blinding was achieved due to the nature of the intervention that includes a training session making it impossible to blind the participants from both groups. Blinding of the researcher was also impossible as the intervention was delivered by the researcher. In this study, only the data collectors and outcome assessors mainly personnel performing audiometry tests were blinded and unaware of the group allocation of participants for both intervention and control group hence reducing the risk of detection bias. Therefore, this study suggests good internal validity and this is a prospective study which allows the researcher to determine allocation and administration of the intervention to a chosen population and reducing allocation bias. The use of per-protocol analytical method also results in loss of prognostic balance afforded by randomization as participants that violated the study protocol were excluded from analysis despite being allocated to intervention or control group at the start of the study (Porta, Bonet, & Cobo, 2007).

The other limitation of this study is external validity in terms of generalizing results from this cluster-randomized trial to populations of vector control workers with different cultural and occupational exposure characteristics as the population studied. It is also important to understand that any changes in work process such as change in model or type of fogging machine used will require area and personal noise monitoring to be repeated.

Long-term effectiveness of this Hearing Conservation Program (HCP) still remains unknown especially with the progressive nature of noise-induced hearing loss (NIHL). The effectiveness of this program in the prevention of NIHL among vector control workers over a long period of time needs to be looked into in order to ensure sustainability and identify potential barriers to implementation of this program in the long run.

The use of a self-administered questionnaire to gather data on sociodemographic characteristics, noise exposure history and knowledge, attitude and practice from the participants may result in information bias. This is because workers may have withheld or manipulated certain information due to fear of losing their job or being transferred out if they were diagnosed with noise-induced hearing loss (NIHL). Recall bias may also occur especially among senior vector control workers who have been employed in multiple jobs before, thus will have difficulty in remembering past employment history related to occupational exposures to noise. This issue is addressed by measuring another objective outcome such as hearing threshold changes or audiometric threshold changes in participants from both groups.

The sampling method used in this study is clustered random sampling and this method of probability sampling enhances participants' compliance and avoids intervention group contamination. However, there is a risk of immigrative selection bias in which new workers were enrolled into the cluster after the baseline due to unseen circumstances such as transfer of workplace or new recruitment and this may lead to loss of precision. This issue is addressed by restriction of eligibility criteria in which clusters of the same size are recruited and also estimating the design effect during sample size determination. During the analysis of the results, the adjusted p-value was calculated to account for the clustering effect.

Hearing threshold level was the primary outcome being measured using audiometric booths and may have resulted in variability in measured audiometric threshold levels. The sources of variability in measured audiometric threshold levels can be due to normal fluctuations in the hearing responsiveness of participants (unavoidable), inconsistencies in audiometric booths and testing methods as well as determining true threshold changes can be a challenge (temporary or permanent threshold shift). Although the booths were calibrated prior to testing to minimize instrument bias, it is operator dependent and may result in observer bias causing inaccurate data. The participants may also malinger due to fear of being diagnosed with hearing impairment resulting in response bias. The possibility of the Hawthorne effect also needs to be taken into consideration as the participants in the intervention group may modify their behavior and practice mainly towards safety and health in response to being observed by the hearing conservation program coordinator.

The effects of certain ototoxic chemicals and hearing has long been studied since chemicals are used extensively at workplaces with recent evidence suggesting certain chemicals such as organic solvents, heavy metals and asphyxiants may cause impairment in the auditory system (Fechter, 2004). However, it is difficult to differentiatie between noise and ototoxic chemical causes of hearing impairments (threshold shifts) just by conducting audiometric testing alone. Besides that, risk of hearing loss can be greater with exposure to both hazards as a result of synergistic effect especially in workplaces with noise levels below the Permissible Exposure Limit (PEL) (National Institute for Occupational Safety and Health USA, 2018). In this study, vector control workers were exposed to chemicals used during fogging activity mainly organophosphate insecticides (Acetellic) and diesel (diluent). The effect of these chemicals on hearing loss would be difficult to determine in this study but the increased risk for hearing loss due to exposure to both chemical and noise hazards cannot be ruled out (Dundar, Derin, Aricigil, & Eryilmaz, 2016; Hoshino, Pacheco-Ferreira, Taguchi, Tomita, & Miranda, 2008; Perry & May, 2008).

Another limitation of this study is new regulations in relation to noise exposure limits will result in the need to review the Hearing Conserevation Progrm (HCP). The gazettement of the new Occupational Safety and Health (Noise Exposure) Regulations 2019 on 1st March 2019 showed changes in the daily permissible exposure limit being reduced from 90 dB(A) to 85 dB(A). However, the sound attenuation achieved with existing hearing protection devices PROGUARD Ultra Ear Muffs (model: PCO5FEM) with a Single Number Rating (SNR) of 32 dB is able to provide adequate level of protection well below the 85 dB (A).

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

6.1.1 Noise exposure level

Vector control workers in the Ministry of Health (MOH), Malaysia are exposed to hazardous noise emitted by the fogging machines. Findings from personal and area monitoring suggest vector control workers under the Ministry of Health (MOH) are exposed to noise levels above the permissible exposure limit (PEL) of 90 dB(A) according to local regulations (Noise Regulation 1989). Therefore, there is a need for a comprehensive hearing conservation program (HCP) to be implemented at all district health offices.

6.1.2 Baseline descriptive findings

Baseline job characteristics indicates that more than 70% of vector control workers involved in fogging activity are mostly made up of general workers and public health assistants and are predominantly from the male population. The proportion of participants with hearing impairment was 11.5% at baseline. Meanwhile the proportion of hearing loss among participants was more evident at high frequencies (3000 Hz, 4000 Hz, 6000 Hz and 8000 Hz) and this ranged from 15% to 23%. This is consistent with progressive loss of high frequency hearing sensitivity observed in cases of noise-induced hearing loss (NIHL). Meanwhile the average score for the domains attitude and practice towards noise-induced hearing loss (NIHL) was below satisfactory levels (<75%) and deemed inadequate with more than 50% of the proportion of participants scoring unsatisfactory scores for each domain.

6.1.3 Effectiveness of the Hearing Conservation Program (HCP)

There was improvement in average hearing threshold levels of participants three months after implementation of the Hearing Conservation Program (HCP). A significant reduction in proportion of participants with hearing loss was also observed especially for higher frequencies (3000 – 8000 Hz). This indicates the program is effective in preventing noise-induced hearing loss (NIHL). However, another primary outcome measured, hearing impairment showed minimal to no reduction in proportion of participants with hearing impairment after three months of receiving the intervention. This could point to a need for a longer follow-up period to observe significant improvement.

In terms of the secondary outcome measured, improvement in knowledge, attitude and practice towards noise-induced hearing loss at one month and three months post-intervention was observed except for the knowledge domain that did not show any improvement after three months of intervention. However, the proportion of participants with satisfactory scores in all domains did not increase at one month and three months post-intervention. This suggest that regular and continuous trainings are urgently needed.

6.2 Recommendations

Despite being highly preventable noise-induced hearing loss (NIHL) remains a significant public health problem being one of the highest reported occupational disease in Malaysia with high economic implications mainly due to compensation even with existing legislation and Hearing Conservation Programs (HCP) in the industries involved. This could be attributed to the low degree of severity of the disease resulting in neglect from the employer, employee and healthcare provider perspective.

Currently there is no existing hearing conservation program (HCP) for vector control workers in the Ministry of Health, Malaysia. This study designs and evaluates an effective Hearing Conservation Program that may be beneficial for future policy development with regards to noise-induced hearing loss (NIHL) prevention programs for vector control workers in the Ministry of Health. Most importantly it will protect the health of our vector control workers and increase productivity especially since fogging to date remains the main method of prevention and control in controlling dengue infection in Malaysia. This hearing conservation program (HCP) will prevent vector control workers from developing noise-induced hearing loss (NIHL) and in turn reduce the overall burden of noise-induced hearing loss (NIHL) in Malaysia. During the process of this study, there were meetings, interviews as well as field visits during fogging activity that helped identify barriers to implementation of preventive measures which is important for implementation of an effective hearing conservation program (HCP) in the future.

Similar studies are needed to look into the long term effectiveness of this program in hearing conservation of workers especially since noise-induced hearing loss (NIHL) is progressive occupational disease that takes 5 to 10 years to occur. The role of enforcement of current policies and legislations also needs to be enhanced to further protect the safety, health and well-being of our vector control workers. Evidence on organizational roles in ensuring a comprehensive and effective hearing conservation program that achieves its objectives also should be further investigated.

The knowledge, attitude and practice of vector control workers in relation to occupational noise exposure needs to be improved through continuous training and health education especially on the negative impact of noise on health. Proper usage and maintenance of hearing protection devices is also important and needs to be given attention.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

The following papers have been presented and submitted from this thesis:

Conference presentations:

1. The Effective Strategies to Prevent Noise-Induced Hearing Loss: A systematic Review. Poster presentation. 5th Regional Conference of Occupational Health, 13th-15th September 2018, Kuala Lumpur, Malaysia. (Winner of best poster)

Publications:

1. Supramanian R.K., Isahak M., Noran N. H. The Effective Strategies to Prevent Noise-Induced Hearing Loss: A systematic Review, ASM Science Journal (Accepted)
2. Supramanian R.K., Isahak M., Noran N. H. Hearing conservation program for vector control workers: Short-term outcomes from a cluster-randomized controlled trial, Asia Pacific Journal of Public Health (Submitted)