THE PATTERN OF PERSONAL LISTENING DEVICE (PLD) USE AMONG UNIVERSITY STUDENTS AND ITS IMPACT ON HEARING STATUS

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by

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CERTIFICATION

This is to certify that the dissertation entitled 'The Pattern of Personal Listening Device (PLD) Use Among University Students and Its Impact on Hearing Status' is a project done by NUR SHAMIN ADRIANA BINTI MOHD AMIN from September 2024 to July 2025 under my supervision. We have read this dissertation and, in our opinion, it fulfils the acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment for the degree of Bachelor of Health Sciences (Honours) (Audiology). Research work and collection of data belong to Universiti Sains Malaysia.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

>	:	More than
≤	:	Less than or equal than
<	:	Less than
%	:	Percent
r	:	Coefficient correlation
p	:	significant
χ^2	:	Chi-Square

LIST OF ABBREVIATIONS

DPOAE	:	Distortion Product Otoacoustic Emission
PTA	:	Pure-tone Audiometry
TTS	:	Temporary Threshold Shift
PTS	:	Permenant Threshold SHift
NIHL	:	Noise-induced Hearing Loss
PLD	:	Personal Listening Device
Hz	:	Hertz

LIST OF APPENDICES

THE PATTERN OF PERSONAL LISTENING DEVICE (PLD) USE AMONG UNIVERSITY STUDENTS AND ITS IMPACT ON HEARING STATUS

ABSTRAK

Kajian ini adalah bertujuan untuk menyiasat corak penggunaan peranti pendengaran peribadi dalam kalangan pelajar universiti dan meneliti potensi kesannya terhadap status pendengaran. Penggunaan peranti pendengaran peribadi telah menjadi hampir universal dalam populasi ini, terutamanya dalam kalangan individu berumur 20 hingga 25 tahun, yang sering menggunakan peranti ini untuk tujuan akademik dan hiburan. Satu tinjauan rentas dan penilaian pendengaran telah dijalankan melibatkan pelajar universiti untuk menilai tingkah laku mendengar mereka, kekuatan bunyi yang mereka guna, dan hubungannya dengan status pendengaran. Data dikumpulkan melalui soal selidik dan penilaian pendengaran termasuk audiometri nada tulen dengan ambang frekuensi tinggi yang diperluas pada 12kHz dan pancaran otoakustik hasil herotan (DPOAE). Keputusan menunjukkan bahawa walaupun kebanyakan pelajar gemar menggunakan peranti pendengaran peribadi pada kekuatan sederhana, ramai juga yang melebihi tahap pendengaran selamat, terutamanya di persekitaran yang bising dimana mereka akan lebih cenderung untuk menguatkan bunyi peranti pendengaran peribadi. Sebahagian besar peserta yang lebih suka tahap kelantangan yang lebih tinggi dan penggunaan harian yang lebih lama menunjukkan meningkatan nilai yang lebih tinggi pada 12kHz dan hasil DPOAE yang berkurangan, menunjukkan perubahan awal pada koklea. Khususnya, 32.3% melaporkan kesukaran mendengar dalam persekitaran bising walaupun keputusan audiometri adalah normal. Ini mencadangkan bahawa kehadiran "*hidden hearing loss*".

Penemuan ini menekankan jurang antara amalan mendengar yang dianggap selamat dan yang sebenarnya dalam kalangan orang dewasa muda dan menekankan kepentingan pendidikan tentang pemeliharaan pendengaran. Kajian ini mencadangkan penggabungan ujian audiometri frekuensi tinggi dan DPOAE dalam saringan pendengaran rutin untuk pengesanan awal kerosakan auditori dan NIHL.

THE PATTERN OF PERSONAL LISTENING DEVICE (PLD) USE AMONG UNIVERSITY STUDENTS AND ITS IMPACT ON HEARING STATUS

ABSTRACT

This study investigated the patterns of PLD use among university students and examined its potential impact on hearing status. PLD usage has become nearly universal in this population, especially among individuals aged 20 to 25, who often use these devices for academic and leisure purposes. A cross-sectional survey and hearing assessment were conducted involving university students to evaluate their listening behaviours, volume preferences, and the relationship to hearing outcomes. Data were collected through questionnaires and hearing assessments including pure tone audiometry (PTA) with extended high-frequency thresholds at 12kHz and distortion product otoacoustic emissions (DPOAE). Results showed that while most students perceived their listening volume as moderate, with many exceeded the safe listening level, particularly in noisy environments. A significant portion of participants who preferred higher volume levels and longer daily usage showed elevated thresholds at 12kHz and reduced DPOAE results, indicating early cochlear changes. Particularly, 32.3% reported difficulty hearing in noisy environments despite normal PTA results, suggesting the presence of hidden hearing loss. These findings highlight a gap between perceived and actual safe listening practices among young adults and underscore the importance of education on hearing conservation. The study recommends incorporating high-frequency PTA and DPOAE in routine hearing screenings for early detection of auditory damages and NIHL.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Hearing loss is considered one of the leading causes of disease burden worldwide. It has become the fourth most common disability globally, with 5-6% of people globally affected by hearing loss (Vos et al., 2016). According to the World Health Organization (WHO) (2024), there are over 430 million people (5%) of the world's population who need rehabilitation for their disabling hearing loss, with 34 million of them children. It is projected that by 2050, at least 700 million people may experience disabling hearing loss and will need hearing rehabilitation. Disabling hearing loss refers to a hearing impairment greater than 40dB in adults for the better hearing ear (WHO, 2021).

Meanwhile, for a child, a hearing loss greater than 30dB in the better ear was considered disabling hearing loss. Disabling hearing impairment can significantly affect one's daily life in many ways. If the hearing loss is prelingual at 2 years old or younger, there is a higher chance that the development of spoken language, reading ability, and educational progress will be affected (Chong, 2023; Vos et al., 2016). However, if hearing loss is acquired later in adulthood or life, it may impair their quality of life. They may face difficulties communicating and interacting with others, which can later impact their social, functional, and psychological well-being (Ciorba et al., 2012).

Several causes may lead to hearing loss at an early age or later. One of them was noise-induced hearing loss (NIHL). NIHL can occur not only in adults but also in all age. Exposure to harmful noise can happen at any age, including children, young adults, and older people. Research by the National Institute on Deafness and Other Communication

Disorders (2014) has shown that about 10 million adults (6%) under the age of 70 years old in the U.S., and as many as 17% of teens aged 12 to 19 years old have features of NIHL on one or both ears in their hearing test results. NIHL is a sensorineural deafness due to long-term noise exposure. In many countries, it is the second leading cause of acquired hearing loss after presbycusis. According to the WHO (2017), an estimated 360 million people globally experience severe hearing loss, while around 1.1 billion young people aged 12 to 35 are at risk of hearing loss due to noise exposure (Ding and Yan, 2019).

NIHL can occur due to prolonged exposure to high noise levels greater than 80 dB SPL. It is the most common form of sensorineural hearing loss (SNHL). It is also known as one of the most significant health concerns for school-age children, as it can impact their ability to engage in daily learning activities and academic performance. Typically, NIHL will develop gradually and progressively and often go unnoticed by those affected (Yusni et al., 2021). According to the World Health Organization (2015), about 1.1 billion teenagers and young adults were at risk of NIHL due to the unsafe use of personal listening devices (PLDs) such as smartphones and involvement in noisy entertainment venues such as nightclubs, bars, and sporting events which leads to the exposure to a damaging level of sound (Tran, 2015). Exposure to loud sounds for long periods cannot only cause temporary hearing loss but also result in tinnitus, which is defined as the ringing sensation in the ear. However, if the exposure is extremely loud and prolonged, it can permanently damage the sensory organs and cells, resulting in irreversible hearing loss (Tran, 2015).

1.2 Problem Statement and Study Rationale

In an era where technology dominates the world, humans have implemented many changes to keep up with the latest trends. Companies producing PLDs are also not exempted from this rapidly evolving technological trend. More and more devices are being created, such as wired and wireless headphones and earphones, earbuds, and bone-conduction headphones. Each device type has advantages, such as noise-cancelling mode, longer battery life, good sound quality, and more. Due to the technology offered, people of all ages, whether young or old, certainly aspire to own it. However, studies have shown that young adults mostly use PLDs. They prefer to use the PLDs for various purposes, such as attending online classes, listening to music, watching videos, using the phone, and isolating themselves from the outside world (Hawari, 2023). However, using them at dangerous volumes and for extended periods will adversely affect an individual. A study has also shown that using PLD at dangerous levels will damage the cells in the cochlea and cause hearing problems in individuals (Peng et al., 2007). The hearing loss may be noticeable and not be discernible by the individual, as the hearing loss is usually affected at 3 kHz – 6 kHz. The other frequencies are primarily within the normal range, so they may not have any difficulty communicating with others.

In this research, the PLD usage patterns of young adults, specifically in the Health Campus of the Universiti Sains Malaysia, will be studied and analysed. A hearing test will also examine the relationship between the individual PLD usage patterns and audiometric characteristics. The association between the two variables will be determined.

The research has been conducted at the Health Campus of Universiti Sains Malaysia, Kubang Kerian, as most students are between 18 and 26 years old. Therefore, this research will focus on their PLD usage pattern, self-reported hearing problems, and hearing test results.

1.3 Research Questions

1. What are the patterns of PLD use among university students regarding duration, volume levels, and device preferences?
2. What is the self-reported hearing status of university students, and how does it relate to their PLD usage habits?
3. Are there significant differences in hearing status between students who engage in high-volume, prolonged PLD use and those who do not?

1.4 Objectives

1.4.1 General Objective

1. To investigate the pattern of PLD use among university students and its impacts on hearing status.

1.4.2 Specific Objectives

1. To assess the frequency and reported volume setting of PLD usage among university students.
2. To determine the association between PLD use and self-reported hearing status.
3. To determine the association between PLD use and the hearing assessment results.

1.5 Hypothesis

1.5.1 Alternative Hypothesis

1. There is a significant association between PLD use and self-reported hearing status.
2. There is a significant association between PLD use and the hearing assessment results.

1.5.2 Null Hypothesis

1. There is no significant association between PLD use and self-reported hearing status.
2. There is no significant association between PLD use and the hearing assessment results.

CHAPTER 2

LITERATURE REVIEW

2.1 Noise and Hearing

2.1.1 Definition of NIHL

Noise can be described as "unwanted sound" or audible acoustic energy negatively impacting a person's physiological or psychological well-being. It can also disrupt an individual's peace or convenience, causing discomfort or disturbance (*What is Noise?*, n.d.). Repeated overexposure to noise at or above 85dBA can cause an individual to experience permanent hearing loss (Themann and Masterson, 2019). NIHL is a type of sensorineural hearing impairment caused by exposure to loud sounds that damage the delicate structures of the hair cells in the inner ear. It is the second leading cause of sensorineural hearing loss after presbycusis, age-related hearing loss. It affected approximately 5% of the world's population (Natarajan et al., 2023a). NIHL is the most common and preventable type of hearing disability. It typically develops gradually over several years due to prolonged and repeated exposure to loud noise or may occur suddenly, depending on the intensity and duration of the noise exposure. Extended exposure to harmful noise can lead to irreversible damage to the sensory hair cells of the cochlea, which is located within the inner ear (Subha and Huda, 2015).

Noise can be categorised into a few types: experimental noise, occupational noise, and non-occupational noise. Experimental noise refers to the sounds deliberately created in a controlled laboratory setting for research and clinical purposes. Some examples of experimental noise include white, pink, and brown noise. On the other hand, occupational noise refers to the hazardous noise present in the workplace. In contrast, non-occupational noise refers to the loud sounds encountered outside work, such as traffic, loud music, or household appliances.

2.1.2 Mechanism of Damage

The damage associated with NIHL begins when harmful sound is channelled to the auditory structures from the outer ear via the auditory canal (Natarajan et al., 2023a). The damage can occur through multiple mechanisms, such as mechanical, ischemic, or metabolic. Regardless of the air cell destruction route, the hair cells do not regenerate. Therefore, once the cells are destroyed, the NIHL is permanent (Themann and Masterson, 2019).

2.1.2.1 *Mechanical Damage*

Hearing loss related to noise exposure can arise from mechanical damage to the hair cells located on the basilar membrane. It is linked to the mechanical shearing forces exerted on the stereocilia of the hair cells in the cochlea. Prolonged and excessive exposure to noise can amplify these forces, leading to core breakage, destruction of the tip links, and damage to the actin structure of the stereocilia, thus causing cellular dysfunction or death. At lower frequencies (below 2 kHz), middle ear muscle reflexes may reduce the impact of these forces, therefore partially protecting the hair cells from damage. Temporary threshold shifts (TTS) may occur if damage is limited, as tip links and actin structures possess some ability to repair themselves within 24 hours. However, excessive damage can result in permanent threshold shifts (PTS), which lead to an irreparable mechanotransduction loss.

Besides, noise will also affect the supporting cells critical to cochlear stability. Noise exposure can also damage the supporting structures, like the pillar, Dieters', and Hensen's cells, which are crucial in maintaining outer hair cell (OHC) integrity. Severe acoustic trauma (160 dB impulse or 100 – 120dB sustained noise) can cause displacement or buckling of these cells, disrupting the connection between OHC stereocilia and the tectorial membrane, reducing the stiffness of the pillar cells and uncoupling OHC stereocilia from the tectorial membrane. This uncoupling results in diminished hair cell stimulation and contributes to TTS. While moderate noise can lead to temporary microchemical changes and decreased pillar cell rigidity, extreme noise levels cause irreversible structural damage, ultimately impairing hearing sensitivity. Although some repair mechanisms exist for stereocilia and supporting cells, excessive or repeated damage can surpass their reparative capacity, leading to irreversible hearing sensitivity loss (Ding and Yan, 2019; Natarajan et al., 2023a).

2.1.2.2 *Oxidative Stress and Reduced Blood Flow*

Apart from their function in the Krebs cycle, the mitochondria also play an essential role in apoptosis and oxidative stress. Following noise-induced trauma, the cellular damage or degradation of the cell connections may lead to the activation of apoptotic pathways in the hair cells through mitochondrial dysfunction. This will lead to an increase in mitochondrial membrane permeability. The release of cytochrome c into the cytoplasm activates caspase enzymes, leading to cell degradation. Reactive oxygen (ROS) and nitrogen species (RNS), including superoxide and peroxynitrite, are key contributors to oxidative damage, persisting for more than ten days post-exposure. While antioxidant enzymes like superoxide dismutase (SOD1), catalase, and glutathione protect against free radical damage, their depletion will increase the vulnerability to permanent threshold shifts (PTS).

The stria vascularis, which is known as a crucial structure for maintaining ionic balance in the cochlea, is highly susceptible to noise trauma. Damage to stria vascularis causes intermediate cells disrupts the endocochlear potential, leading to ionic imbalances such as elevated $K+$ in the endolymph and $Na+$ in the perilymph. It will result in cellular oedema and impaired hair cell function. Noise-induced vasoconstriction and reduced blood flow further aggravate hypoxia and oxidative stress, amplifying cellular damage. This vascular injury also activates stress pathways like the JNK cascade, which triggers pro-apoptotic responses, further contributing to cell death. Persistent oxidative damage and ischemia highlight the extended timeframe for NIHL to progress.

Magnesium deficiency exacerbates the effects of noise trauma by disrupting ionic homeostasis and vascular regulation. Magnesium is a vasodilator and calcium channel blocker mimic that helps to regulate the calcium and potassium levels. Reduced magnesium levels increase calcium influx and potassium efflux, causing cellular energy depletion and enhanced membrane permeability. This imbalance also promotes vasoconstriction, increased blood viscosity, and further reductions in cochlear blood flow, intensifying the effects of oxidative and vascular damage. These factors create a cascade of mitochondrial dysfunction, oxidative stress, and ionic imbalances that drive NIHL progression (Natarajan et al., 2023a).

2.1.2.3 *Inflammation*

Neuroinflammation plays a vital role in maintaining nervous system homeostasis but is also implicated in NIHL. Noise trauma induces pro-inflammatory cytokines such as tumour necrosis factor-alpha (TNF-α), interleukins, and chemokines like CCL2 in the cochlea. This inflammatory response also recruits immune cells, including macrophages, to the cochlea. While it remains unclear whether inflammation directly causes or exacerbates the auditory threshold shifts in NIHL, some inflammatory molecules exhibit ototoxic effects. For instance, TNF-α perfusion in guinea pig cochleae has been shown to cause synaptic degeneration and reduce auditory nerve activity, effects that can be mitigated by blocking TNF-α (Ding and Yan, 2019; Natarajan et al., 2023a).

2.1.2.4 *Excitotoxicity and Synaptopathy*

Louder sounds can overstimulate hair cells in the ear, leading to more glutamate release and increased movement of outer hair cells. However, noise exposure can cause irreversible damage by destroying the synapses between inner hair cells (IHCs) and nerve cells, known as synaptopathy. This damage is worsened by glutamate excitotoxicity, where excessive glutamate release causes an ion imbalance that leads to swelling and degeneration of nerve cells over time. Even if hearing thresholds return to normal, the damage can continue, affecting brain function and nerve activity.

Noise can also cause synaptopathy, damaging the synapses and nerve fibres connected to hair cells, even at noise levels that do not cause immediate hearing loss. This hidden damage, called "hidden hearing loss," cannot be detected by standard hearing tests, but it still impacts hearing. Some nerve cells are particularly vulnerable to excitotoxicity due to their structure and response to glutamate, which explains why synaptopathy may occur without detectable changes in hearing thresholds (Natarajan et al., 2023a).

2.1.3 The effect of NIHL

NIHL develops slowly after many years of exposure and can have a range of effects on individuals (Mathur, 2022). Permanent sensorineural hearing loss is one of the most common and severe effects of exposure to hazardous noise. It is typically characterised by a “notch” in the configuration of audiometric thresholds. The poorest thresholds often occur in the 3000Hz to 6000Hz range, with better thresholds occurring above and below these frequencies (Themann and Masterson, 2019). Most cases of NIHL are bilateral, although unilateral notches can occur when the noise exposure is substantially louder in one ear than the other. Some individuals with NIHL may also experience a temporary threshold shift. It is common in persons exposed to excessive noise, as they represent a transient hair cell dysfunction. Although complete recovery can occur, repeated episodes of such a shift occurring after exposure to hazardous noise can give way to a permanent threshold shift as the hair cells in the cochlea are progressively lost during each exposure episode (Rabinowitz, 2000). Due to the hearing loss limited to high frequencies, individuals with NIHL are unlikely to have a problem understanding speech in a quiet environment. Still, they may have difficulty communicating and understanding speech when high ambient background noise exists. As NIHL progresses, they may also have trouble understanding a high-pitched voice, especially women’s and children’s, even in a quiet conversational environment (Mathur, 2022).

Besides hearing loss, individuals with NIHL will also experience tinnitus associated with temporary or permanent threshold shifts. Tinnitus is the conscious perception of sound without an external auditory stimulus, which is often experienced as ringing and buzzing in the ear. It is typically self-reported and is primarily subjective. Exposure to loud noises from work, leisure activities, or firearms has been linked to a higher risk of developing tinnitus. In this condition, individuals hear ringing or buzzing sounds in their ears (Shore and Wu, 2019). The exact cause of tinnitus is still being studied, but it is believed that damage to the cochlea (part of the inner ear) and the loss of nerve connections may play a role. Neuroinflammation, which involves inflammation in the brain's auditory regions, is also thought to contribute to tinnitus. Research has shown that noise-induced damage can trigger increased levels of inflammation and activation of specific cells in the brain, further worsening tinnitus symptoms (Natarajan et al., 2023).

NIHL not only affects an individual's auditory sensitivity but may also cause psychological effects and impact their social life. A study has been conducted and showed that NIHL can accelerate cognitive decline, particularly in older adults. The condition will disrupt auditory processing, which is crucial for the hippocampus, a brain region involved in memory and spatial navigation. Reduced auditory input to the brain can impair an individual's neurogenesis and cognitive functions, leading to difficulties with memory retention and spatial awareness. Chronic noise exposure can also elevate stress hormones like corticosterone, further exacerbating cognitive deficits and contributing to conditions such as dementia and Alzheimer's disease if the condition is prolonged without any proper management (Manohar et al., 2022).

Individuals with NIHL are also at a higher risk for mental health problems, including depression and anxiety. The stress associated with hearing loss can lead to feelings of isolation, frustration, and helplessness. Chronic noise exposure has been linked to increased levels of anxiety-like behaviours and depressive symptoms in both human studies and animal models. This connection is partly due to the neuroinflammatory responses from noise exposure, which can affect brain function and emotional regulation (Hahad et al., 2024). Untreated mental health problems will also lead to other issues, such as social withdrawal and isolation. Those with NIHL may avoid social interaction as they may feel stressed and left out due to communication difficulties. Consequently, the quality of life of those with NIHL may decline drastically due to communication challenges with others, significantly if it affects their job and careers (Hahad et al., 2024). Therefore, NIHL not only affects hearing but also has profound psychological effects that can lead to cognitive decline and mental health issues while simultaneously impacting social interactions and overall quality of life.

2.1.4 Diagnosis of NIHL

2.1.4.1 Pure-tone Audiometry (PTA)

PTA is performed as a baseline evaluation test for hearing loss. The air and bone conduction tests are typically conducted at 125 Hz to 8000 Hz frequencies. The audiometric characteristics signatures of NIHL will be hearing is normal from low to mid frequencies, and there is a sudden drop past 3000Hz, most pronounced at 4000Hz and a slight recovery in higher frequencies. Many factors can result in such audiogram patterns, such as the length and volume of the outer ear canal and the outer ear resonant frequency. The notch in the audiogram can deepen, involving higher and lower frequencies as the duration of noise exposure increases, as shown in Figure 1.

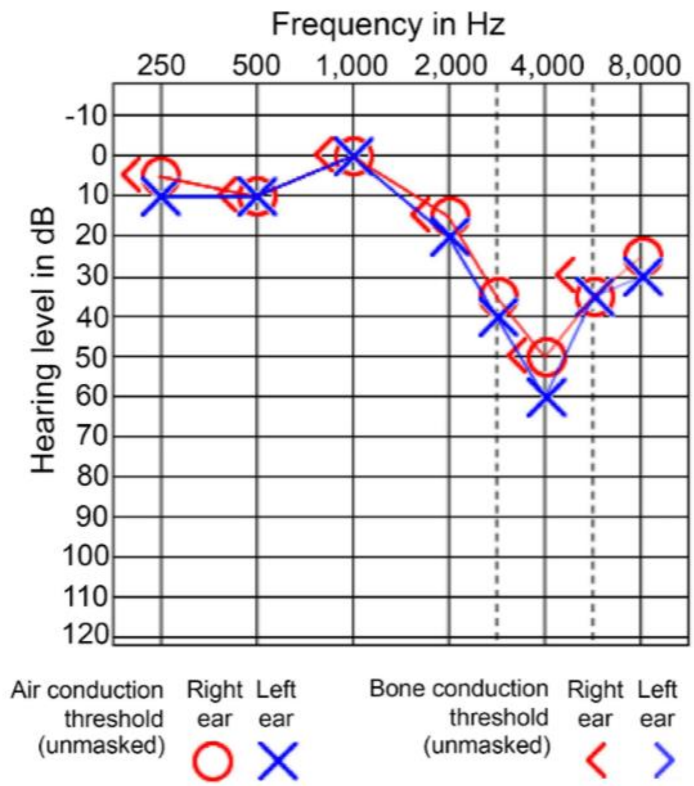

Figure 1 Pattern of Audiogram for NIHL (Natarajan et al., 2023)

Figure 1 indicates the pattern of the audiogram in a case of NIHL, where a sharp notch can be seen at the frequency of 4kHz, with a decrease of the hearing threshold at the adjacent frequency, 3kHz, and a rise back in threshold at 6kHz and 8kHz.

2.1.4.2 Distortion Product Otoacoustic Emissions (DPOAE) Measurement

The OHCs amplify the intensity and sharpen the peak of the travelling sound wave in the cochlea via prestin-mediated elongation and contraction. The nonlinear electromechanical distortion of sound waves caused by outer hair cell (OHC) motility can be assessed using distortion product otoacoustic emissions (DPOAE) testing. Beyond distortion, otoacoustic emissions also arise from the reflection generated by the random scattering of the incoming travelling wave. Consequently, the presence of DPOAEs is a reliable indicator of normal cochlear function and, specifically, the health of OHCs. Reduced DPOAE amplitudes are commonly observed in older individuals, those with noise exposure, and patients with cochlear disorders. It makes DPOAE testing a versatile tool with various clinical applications, including newborn hearing screening, diagnostic audiological evaluations, monitoring for ototoxicity, and studying cochlear mechanics. In military-related NIHL, DPOAE testing may offer advantages over PTA as it is faster, easier to administer, and effective at detecting early cochlear damage caused by noise exposure (Natarajan et al., 2023).

2.1.4.3 Speech-in-Noise Test

While PTA testing helps identify hearing loss, it does not account for the ability to discriminate sound in background noise, which is the primary complaint presented by patients with NIHL. PTA is limited in effectively predicting speech perception because it indicates the patient's access to sound rather than their functional hearing ability (Natarajan et al., 2023). Speech-in-noise tests are critical in assessing hearing ability in individuals with NIHL as they measure and estimate how well a person can understand speech in background noise. Thus, providing an insight into their functional word recognition capabilities. This testing is a valuable diagnostic tool for identifying NIHL, especially when the PTA shows normal hearing. Still, the individual presents with significant difficulties in a noisy environment.

2.2 Personal Listening Device (PLD)

For many young people, exposure to music from personal listening devices may represent a significant component of daily noise dose (Dirks et al., 2021). A PLD is a personal audio system often used with a smartphone, laptop or tablet. Many styles of PLDs are available, such as over-the-ear headphones, earphones and wireless earbuds. Each style of the PLDs will produce a different sound pressure level (SPL) in the ears, depending on the listening environment and the user's preferred listening levels (PLLs). Although the PLLs were based on the subjective judgment of the users, studies have shown that the earphones resulted in a higher PLL.

Comparatively, the over-the-ear headphones resulted in a significantly lower PLL (Hodgetts et al., 2007). The design of the in-the-ear earphones is mainly made to be in-ear models, causing the devices to sit closer to the eardrum than the over-the-ear headphones, thus increasing the intensity of the sound reaching the ear. If used for extended periods, the chances for individuals to develop NIHL were higher when using the earphones than those who used the over-the-ear headphones ("The Impact of Earphone and Headphone Use on Hearing Loss," 2024). The over-the-ear headphones were generally considered safer than earphones because their proximity to the eardrum was greater, and they distributed the sound over a larger area than earphones. Thus, it can potentially reduce the risk of NIHL ("How Different Types of Headphones Affect Your Hearing," 2024).

In 2021, PLD use may be the leading source of everyday non-occupational noise exposure, especially for children, teens, and young adults. Research shows that PLD is widely used, especially among teenagers and young adults. Most users listen to these devices nearly daily, often at high volumes. Studies have also found that PLD users are more likely to experience auditory disorders, such as hearing loss and tinnitus, with some cases reported in children as young as 9 to 11 years old. In the United States, the average PLD user spends about 4.5 hours per day listening (Fink and Mayes, 2021).

Listening Situation	Average noise level	Reference
Ambient quiet	79.2-82 dBA	Muchnik et al.[45], Friesen & Papadopoulos[46]
Ambient noise	89 dBA	Muchnik et al.[45]
Urban environments	94.1 dBA	Fligor et al.[47]
Typical volume range	68-86 dBA	Basner et al.[48]
Typical volume range	75-105 dBA	WHO[36]

Table 1 The Average of Noise Level When Using PLD at different Listening Situation.

Note: From Fink and Mayes (2021), Personal Audio System User Noise Levels

Table 1 showed the average noise level applied by the teens and young adults when using the PLD at different listening situation at noted by Fink and Mayes (2021) in their research.

While significant noise exposure often occurs in the workplace, a large portion of daily noise exposure for many people comes from leisure activities. Among these, the use of PLD has emerged as a key concern. When used in noisy environments, such as during commutes or at the gym, the users tend to increase the volume to compensate for background noise, which increases their risk of high noise exposure (Kaplan-Neeman et al., 2017).

A nationwide study in Australia revealed that 62% of PLD users listen to their devices while commuting, with 16% of total listening time occurring during these periods. Teenagers aged 15 to 19 were found to use their PLD the most, averaging 88 hours per month, followed by young adults aged 20 to 29, who averaged 72 hours per month. Furthermore, research indicates that higher background noise levels lead listeners to select higher volume settings, exacerbating their overall noise exposure (Dirks et al., 2021).

2.3 Effect of loudness and prolonged usage of PLDs

Loudness and prolonged use of PLD can result in significant hearing loss. The PLD is said to be able to produce SPLs that exceed the safe listening threshold at 85 dBA. However, the maximum volume settings of a PLD can reach SPLs between 91dBA and 121dBA, while some devices even exceed 130dBA. Continuous listening at these levels can significantly increase the risk of permanent hearing damage (Singh and Sasidharan, 2016). Research has also found that due to the improper use of these devices, the concern regarding the risk of hearing damage also increases, especially among teenagers and young adults, due to the popularity of PLD use (Sulaiman et al., 2013).

The duration of noise exposure is also an essential factor for NIHL. Research byMourad Abd El-Mawgoud (2020)has shown that a more significant hearing threshold shift occurred in the PLD group, which had used it for more years, mainly in the 14 kHz and 16 kHz ranges. In other words, the risk of hearing impairment increases with a longer duration of noise exposure (Mourad Abd El-Mawgoud, 2020). In addition, using earphones for more than 2 hours will also impact hearing loss and may lead to permanent deafness. A study by Cerquone et al. (2006) found that 78% of adolescents used earphones connected to cellphones for music, 12% used MP3 players, and 35% used laptops (Singh and Sasidharan, 2016). Daily use of earphones at high volumes (greater than 85 dB) for extended periods (around 1-3 hours or more) is a significant risk factor for Noise-Induced Hearing Loss (NIHL) (Yusni et al., 2021).

2.4 Conceptual Framework

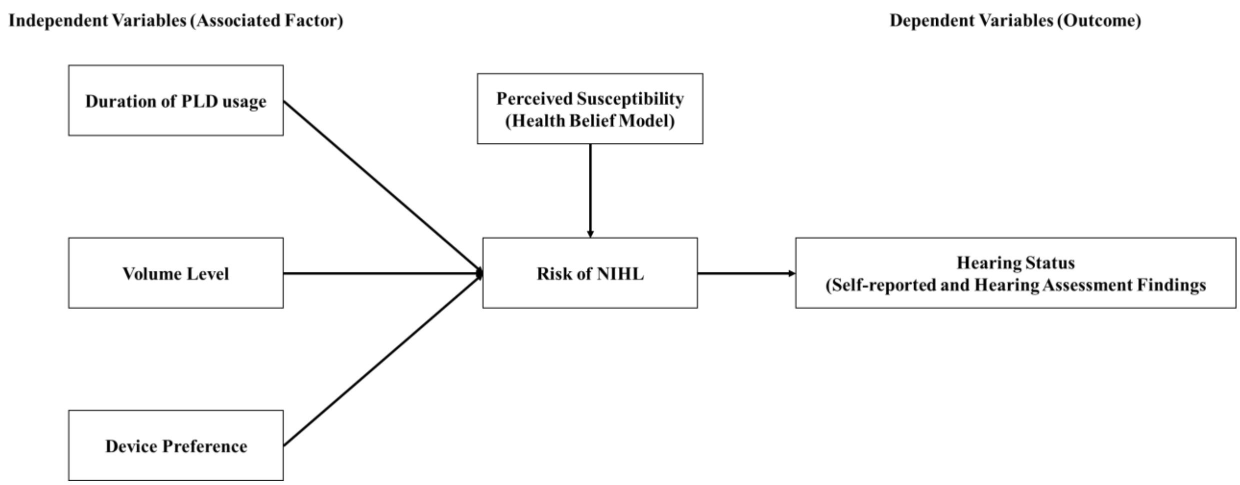

Figure 2: Conceptual Framework: Illustrated the relationship between PLD use and hearing outcomes among university students.

Figure 1 illustrates conceptual framework of the relationship between PLD use and hearing outcomes among university students. Independent variables contribute to the risk of NIHL. The perceived susceptibility was adapted from the Health Belief Model acts as a mediating factor that influences the listening behaviours which determine the outcomes.

CHAPTER 3

METHODOLOGY

3.1 Research Design

This cross-sectional study was conducted among students in the Health Campus, Universiti Sains Malaysia. It is an experimental design, as the participants was recruited for hearing assessments after gathering information about their demographics and personal listening device use patterns.

3.2 Study Area

The study area was at USM Audiology Clinic, Pusat Pengajian Sains Kesihatan, Kubang Kerian, Kelantan.

3.3 Study Population

The targeted population for this study were young adults aged 18 to 26 years old (Bonnie et al., 2015) of the Universiti Sains Malaysia Health Campus. It involved students from various academic programmes and schools, such as the School of Medical Sciences, the School of Dental Sciences, and the School of Health Sciences, on campus. This study also included young adult participants from different academic years.

3.4 Subject Criteria

3.4.1 Inclusion Criteria

1. University students (18-26 years old) of Health Campus, Universiti Sains Malaysia
2. Users of personal listening devices (PLD)

3.4.2 Exclusion Criteria

1. Individuals with middle ear problems
2. Individuals with conductive and mixed hearing loss
3. Individuals who were wearing hearing aids
4. People who cannot understand instructions

3.5 Sample Size Estimation

The sample size was estimated based on the central limit theorem, which stated that the sampling distribution of the sample mean will be approximately normal if the sample size is sufficiently large, regardless of the shape of the population distribution (Kwak and Kim, 2017). A minimum of 30 participants was required to ensure the estimation was reliable to approximate normality. A 10% of dropout rate was taken into consideration. Therefore, a total of 33 participants were recruited to achieve the target analysis sample of 30 participants.

$$\text{10\% of dropout} = 30(n) \times 10\% = 3$$

$$\text{Total of participants (N)} = 30 + 3 = 33 \text{ participants}$$

3.6 Sampling method and subject recruitment

This research study used purposive sampling, a non-probability sampling method. Purposive sampling was used in research studies to choose a specified set of individuals for analysis. This sampling method was helpful when the researcher clearly understands the features or attributes they want to investigate and wants to choose a sample representative of those characteristics (Dovetail Editorial Team, 2023). People who do not fulfil the selection criteria for the research study was excluded from the research.

3.7 Research tools

1. Google form questionnaire

A Google form questionnaire was distributed first to the study population through flyers, emails and social media platforms. The questionnaire aimed to study the participants' usage patterns and habits of the PLDs. The questionnaire included the duration of usage, the volume of usage, device preference, and the situation in which the PLDs were used the most.

2. Otoscopy

Otoscopy is a clinical procedure used to inspect the structures of the ear, specifically the outer ear, external auditory canal, tympanic membrane and middle ear. It is a routinely performed test as it plays a crucial role in diagnosing several ear conditions such as otitis external, acute otitis media and unhealthy tympanic membrane. The otoscope consists of light with a magnifying lens to light up and enlarge the ear structure to help the examiner accurately visualise and examine the conditions of the visible anatomical structures (Falkson et al., 2022).

3. Tympanometer (GSI Tympstar Pro)

Tympanometry is an objective test that helps diagnose an ear problem that can lead to hearing loss (WebMD Editorial Contributors, 2023). It is used to examine the middle ear functions by measuring the stiffness and mobility of the tympanic membrane. A 226Hz tympanometry will be used for the study, as 226Hz tympanometry has become the gold standard test for the middle ear in adults (Amplivox, 2022). The procedure of tympanometry involves inserting a probe into the outer ear canal and creating an airtight seal. The probe contains a tiny speaker, a microphone and an air pump. A 226Hz tone will be introduced through the speaker into the ear canal and transmitted to the tympanic membrane. Some sounds will be passed through the middle ear, while some will be reflected off the tympanic membrane. The microphone on the probe will pick up the reflected sound, and a tympanogram graph showing the compliance, ear canal volume and the tympanic membrane peak pressure of an individual will be the result (Brennan, 2021).

4. Audiometer (GSI Audiostar Pro)

Audiometer is used for pure-tone audiometry (PTA). It is a standard test used to estimate the hearing level of an individual. It is a behavioural test as it requires responses from the patient and is used to measure hearing sensitivity. Various frequencies and intensity ranges are introduced to determine the hearing level. Usually, 250Hz to 8000Hz is used in testing to determine the air conduction thresholds, as it is the range that represents most of the speech spectrum (Walter Kutz, 2023). In this study, the extended high-frequency PTA will also be conducted in detecting the NIHL, as significantly higher hearing thresholds of 10kHz to 16kHz were found in a population that used the PLDs for longer than 5 years (Škerková et al., 2021). A TDH and HDA headphones was used in determining the air conduction hearing threshold. The headphone transducer delivered the pure-tone stimulus presented by the audiometer to the external auditory canal and transmits it to the middle ear and inner ear through air conduction. The transmission of sound through an air conduction medium is crucial in determining the degree of hearing loss. On the other hand, the bone conduction threshold was obtained by placing a bone vibrator behind the ear on the mastoid bone. The bone vibrator delivered the pure-tone stimulus that the audiometer presents through the bone conduction pathway and directly to the inner ear. The bone vibrator determines the bone conduction thresholds and type of hearing loss.

5. Distortion Product Otoacoustic Emission (DPOAE)

DPOAE test will measure the emission of the OHCs in the cochlea. The result was a pass if the signal-to-noise ratio (SNR) was more than 5dB.

3.8 Data collection method

The data collection was conducted from 11th of April 2025 until 31st of May 2025 after gaining ethical approval from the Jawatankuasa Etika Penyelidikan Manusia (JEPeM) USM. A poster to promote the research was distributed and shared through emails, flyers and social media platforms such as WhatsApp. The poster included the link for registration through Google Forms, the selection criteria and the research benefits to the participants. The young adults interested in being part of the study must fill out the Google Form and answer a few questions. The questions covered the participant's demographic information, and 5 minutes may be needed to complete the form. The questions are as follows:

A. Participants' Demographic Information

i. Contact Number

ii. Age

iii. Gender