GHANA COLLEGE OF PHYSICIANS AND SURGEONS

FACULTY OF OTOLARYNGOLOGY

OCCUPATIONAL NOISE EXPOSURE AND HEARING LOSS AMONG CEMENT BLOCK FACTORY WORKERS: A COMPARISON OF TWO ASSESSMENT METHODS

SUBMITTED TO THE FACULTY OF OTOLARYNGOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE CONFERMENT OF A FELLOWSHIP OF THE GHANA COLLEGE OF SURGEONS (FGCS)

BY

DR. GRACE NAA AGOWA AMOO-QUAYE

SEPTEMBER 2022

DECLARATION

I hereby declare that I exclusively undertook the study reported therein and that it contains no material hitherto published by another person which has been accepted for the award of any other fellowship or degree, except portions where references have been accordingly cited.

DR GRACE NAA AGOWA AMOO-QUAYE

(BSc, MBChB, MGCS (ORL)

E.N.T UNIT, KORLE BU TEACHING HOSPITAL, ACCRA, GHANA

.... **18 – 10 - 2022**

Signature **Date**

Telephone no: +233(0)205 196 611/+233(0)244 482 794

Email: amooquaye@yahoo.com

OCCUPATIONAL NOISE EXPOSURE AND HEARING LOSS AMONG CEMENT BLOCK FACTORY WORKERS: A COMPARISON OF TWO ASSESSMENT METHODS

DR GRACE NAA AGOWA AMOO-QUAYE

(BSc, MBChB, MGCPS (ORL)

E.N.T UNIT,

KORLE BU TEACHING HOSPITAL, ACCRA, GHANA

THIS DISSERTATION WAS SUPERVISED BY

DR KENNETH KOJO KORANTENG BAIDOO (FGCS, FWACS)

CONSULTANT ENT SURGEON, HEAD OF NEW ALLIED SURGERY SUB-BMC

HEAD OF EAR, NOSE AND THROAT UNIT

KORLE BU TEACHING HOSPITAL

ACCRA, GHANA

…………………………

DR ADAM ALHASSAN JANGU (FGCS, FWACS)

CONSULTANT ENT SURGEON

EAR, NOSE AND THROAT UNIT,

KORLE BU TEACHING HOSPITAL

ACCRA, GHANA

…………………………………………………………

DR KAFUI KOFI SEARYOH (FGCS, FWACS)

EAR, NOSE AND THROAT UNIT

DEPARTMENT OF SURGERY, KORLE-BU TEACHING HOSPITAL

ACCRA, GHANA

SIGNATURE

…………………………

ATTESTATION BY THE HEAD OF UNIT

DR KENNETH BAIDOO (FGCS, FWACS)

CONSULTANT ENT SURGEON

HEAD OF NEW ALLIED SURGERY SUB-BMC

HEAD OF EAR, NOSE AND THROAT UNIT

KORLE-BU TEACHING HOSPITAL

ACCRA, GHANA

18 – 10 - 2022

Signature **Date**

ACKNOWLEDGEMENT

I am most thankful to the Almighty God without whom this would have been impossible. My most sincere gratitude goes to Prof Emmanuel D. Kitcher for his immense contribution towards the completion of this work. I would like to acknowledge my supervisors, Dr Kenneth K.K. Baidoo, Dr Adam Alhassan Jangu and Dr Kafui Kofi Searyoh for their suggestions and guidance in bringing this work to a successful completion.

To Mr. Joseph Omane-Boateng, Mrs. Jemima Fynn, Mr. Stephen Botchway and the entire staff of the ENT and Audiology Units, I say thank you.

To all the managers and workers of the participating block factories and all staff of Korle-Bu Teaching Hospital who willingly participated, I cannot thank you enough.

I would also like to thank Rev. Tom Ndanu and Dr Antoinette Bowan for their contribution.

To Dr. Frank Hayford and the entire family, your academic and emotional support have been immeasurable. May God bless you all.

ABSTRACT

Introduction

Occupational exposure to excessive noise leading to sensorineural noise induced hearing loss is becoming more pertinent in developing countries as industrialization and infrastructure development increase. The need to develop a tool that efficiently detects this phenomenon as well as the need to, map out noise exposure by industry to enable stronger preventive measures' enforcement is becoming more relevant. Hence, the aim of the study was to determine and compare the prevalence of hearing loss among cement block factory workers using two hearing assessment methods, evaluate their knowledge of the effects of noise on hearing, noise level exposure and assess their knowledge and use of hearing protection devices (HPDs).

Methods

A comparative cross-sectional study was designed to investigate hearing loss among a group of 143 cement block factory workers and 132 controls from March 2021 to December 2021. A semi-structured questionnaire was used to assess knowledge of the effects of noise on health and use of HPDs. Pure tone audiometry (PTA) (conventional and extended high frequency (EHFA) was used to measure hearing threshold levels to determine prevalence of hearing loss and distortion products otoacoustic emissions (DPOAEs) were measured to determine reduced amplitudes. Comparisons of the pure tone averages between the noise exposed and the nonexposed groups was done by independent t-tests, whilst comparisons of percentages of individuals with hearing loss was done using chi-square tests. Statistical significance was set at $p<0.05$.

Results

The mean age of the cases was 29.3 years ±9.2 years compared to that of the controls which was 28.6years ± 6.7 years. The mean duration of work for cases and controls was 3.0years ± 3.2years and 4.4years ± 3.57 years respectively. About half (51.6%) had awareness of the effects of noise on health among block factory workers with usage of hearing protective devices among very few (16.1%). The mean maximum noise level in the block factories was very high (101.8± 4.5dBA). The prevalence of hearing loss was significantly higher among cases than controls by all methods. For the better hearing ear, it was 14.7% among cases and 3% among controls. Extended high frequency audiometry yielded 41.6% hearing loss prevalence among the noise exposed but 15.9% among the nonexposed. Low amplitude DPOAE was recorded 43% among cases and 31.8% in the control group and this was significantly higher than for pure tone audiometry ($p<0.05$) in both groups.

Conclusion

Hearing loss prevalence was higher among cases than controls. DPOAEs detected the most abnormalities as compared to conventional PTA and EHFA. Though roughly half of the block factory workers had some knowledge of the effect of noise on their health and of HPDs, only few of them used the protective devices. The current study also showed that noise levels in all the block factories exceeded the permissible industrial noise levels.

***Keywords*:** Cement block factory workers, noise induced hearing loss, pure tone audiometry (conventional and extended), and distortion products otoacoustic emissions

TABLE OF CONTENTS

DECLARATION ii

ATTESTATION BY THE HEAD OF UNIT v

ACKNOWLEDGEMENT vi

ABSTRACT vii

CHAPTER ONE 1

INTRODUCTION 1

1.1 Background 1

1.2 Problem Statement 3

1.3 Rational for the Study 5

1.4 Aim and Objectives 5

1.4.1 Aim 5

1.4.2 Specific Objectives 5

1.4.3 Null Hypothesis 6

1.4.4 Alternative Hypothesis 6

CHAPTER TWO 7

LITERATURE REVIEW 7

2.1.1The Hearing Mechanism 7

2.1.2 The Auditory System and the Hearing Mechanism 12

2.2.1 Pure Tone Audiometry 17

2.2.2 Extended High Frequency Pure Tone Audiometry (EHFPTA) 24

2.2.3 Otoacoustic Emissions 25

CHAPTER THREE 43

3.0 MATERIALS AND METHODS 43

3.1 Study Design 43

3.2 Study Population 43

3.3 Study Site 43

3.4 Inclusion and Exclusion Criteria 46

3.5 Sampling 46

3.5.1 Sampling Procedure 46

3.5.2 Sample Size Determination 47

3.6 Data Collection Procedure 48

3.8 Data Management and Analysis 50
3.9 Ethical Consideration 51
CHAPTER FOUR **53**
4.0 RESULTS **53**
4.1 Overview of Data 53
4.2 Demographic characteristics of block factory workers and controls 53
4.4.2 Hearing Protection Device Knowledge and Use 60
4.5 Noise Levels in Block Factories 62
4.6 Hearing Thresholds Using Pure Tone Audiometry Assessment 64
4.6.1.1 Conventional Pure Tone Audiometry 66
4.6.1.2 Extended High Frequency Pure Tone Audiometry 81
4.6.2 Distortion Product Otoacoustic Emission Amplitudes 84
4.7 Comparison of Prevalence of Hearing Loss Between Audiological Assessment Methods and DPOAE 89
CHAPTER FIVE **93**
DISCUSSION **93**
5.1 Introduction – Demographic Data 93
5.2 Knowledge on the effects of noise on health 96
5.3 Knowledge and use of Hearing Protective Devices 96
5.4 Noise levels in industry 97
5.5 Hearing loss prevalence using conventional Pure Tone Audiometry 98
5.6 Hearing loss prevalence using Extended High Frequency Pure Tone Audiometry 99
5.7 Hearing loss prevalence using DPOAE 100
5.8 Limitations of the Study 100
CHAPTER SIX **101**
CONCLUSION AND RECOMMENDATIONS **101**
6.1 Conclusion 101
6.2 Recommendations 102
REFERENCES **103**
APPENDICES **114**
1.0: Questionnaire 114
2.0 Hearing Assessment Report Form 116
3.0 Participant Information Sheet 117
4.0 KBTH IRB Approval Letter 121

5.0 Puretone Audiometry 122
6.0 Sentiero DPOAE Device 123
7.0 Locally-manufactured cement block making machine 124
8.0 High output cement block making machine 125
9.0 Noise level measurement 126

List of Tables

Table 2.1: Permissible noise level exposure……………………………………………………….30

Table 4.1: Demographic characteristics of study participants……………….……………..…………55

Table 4.2: Noise levels of block factories in full operation………………………………..……….63

Table 4.3: Mean hearing thresholds of participants…………………….…………………….……65

Table 4.4a: Hearing threshold levels using cPTA among cases……………………...……….67

Table 4.4b: Hearing threshold levels using cPTA among controls……..………………………68

Table 4.5: Hearing levels using cPTA among cases and controls……………...………….…….69

Table 4.6a: Prevalence of hearing loss using pure tone averages for right ear.……….….….…71

Table 4.6b: Prevalence of hearing loss using pure tone averages for left ear.………...…….….…71

Table 4.7: Grades of hearing loss in the better hearing ear…………………….…….…….….75

Table 4.8: Audiometric notch distribution of subjects…………….……………………………80

Table 4.9a: Hearing thresholds levels using EHF audiometry among cases………………….…82

Table 4.9b: Hearing thresholds levels using EHF audiometry among controls…...…………..…82

Table 4.10: Hearing loss prevalence using EHF among cases and controls…………………….83

Table 4.11a: DPOAE amplitudes of cases and controls………………………….….….….……87

Table 4.11b: Prevalence of low DPOAE amplitude among cases and controls…………………88

Table 4.12: Prevalence of hearing loss and DPOAE amplitudes among cases and controls…….90

Table 4.13: Comparison of hearing assessment methods among cases……….………...……….92

List of Figures

Figure 2.1: Anatomy of the ear ……………………………………………………………..…7

Figure 2.2: The bony and membranous labyrinth of the inner ear…………………….………9

Figure 2.3: Anatomy of the cochlea……………….……………………………………………11

Figure2.4: Transmission of sound waves to the cochlea…………….……………………………13

Figure 2.5: An audiograph……………………………………………………………...…18

Figure 2.6: An audiogram demonstrating normal hearing thresholds bilaterally…………………20

Figure 2.7: An Audiogram showing left conductive hearing loss……………….………...…21

Figure 2.8: An audiogram showing bilateral sensorineural hearing loss………………..…...…22

Figure2.9: An audiogram showing left mixed hearing loss………………………….……….23

Figure 2.10: Hearing protective device – an ear muff……………………………..……..…35

Figure 2.11: Hearing protective device – ear plugs (custom molded) ……………………...…37

Figure 2.12: Hearing protective devices – regular ear plugs……………………………………38

Figure 2.13: Hearing protective devices – specialist ear plugs for certain occupations……...…38

Figure 2.14: Hearing protective devices – semi-insert device…………………………..…..…39

Figure 4.1: Age distribution of study participants………………………………………………56

Figure 4.2: Educational level of study participants……...……………………………………57

Figure 4.3: Knowledge of the health effects of noise among cases......…………………….…………59

Figure 4.4: Reason for non-use of hearing protective devices….……………………….………61

Figure 4.5: Prevalence of hearing loss in the better hearing ear of cases and controls…………73

Figure 4.6: Hearing loss prevalence among subjects by ears……………………………………74

Figure 4.7: Duration of work and hearing loss among block factory workers……....…………77

Figure 4.8: Job description and hearing loss among block factory workers ……………………79

Figure 4.9a: Mean DPOAE amplitudes of study subjects (Right ear) …………….……………84

Figure 4.9b: Mean DPOAE amplitudes of study subjects (Left ear) ……………………………85

List of Abbreviations

1. cPTA	Conventional Pure Tone Audiometry
2. DPOAE	Distortion Product Otoacoustic Emissions
3. EHFA	Extended High Frequency Audiometry
4. HCP	Hearing Conservation Programme
5. HPD	Hearing Protective Devices
6. GDP	Gross Domestic Product
7. NIHL	Noise Induced Hearing Loss
8. NIL	Noise Immission Levels
9. NIOSH	National Institute for Health and Safety
10. NRR	Noise Reduction Rating
11. ONIHL	Occupational Noise Induced Hearing Loss
12. PLD	Personal Listening Devices
13. PTA	Pure Tone Audiometry
14. $PTA_{.5124}$	Pure Tone Average of .5,1.2 and 4kHz
15. PTA_{234}	Pure Tone Average of 2,3 and 4kHz
16. PTA_{346}	Pure Tone Average of 3,4 and 6kHz
17. PTS	Permanent Threshold Shift
18. SNHL	Sensorineural Hearing Loss
19. TEOAE	Transient Evoked Otoacoustic Emission
20. TEOAE-MLS	TEOAE – Maximum Length Sequences
21. TTS	Temporary Threshold Shift
22. WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

The superior ability of man to communicate is that which sets him above other animals. This ability is facilitated greatly by his being able to hear such that a child born with hearing impairment severe enough is unable to develop speech without intervention.[1] Hearing loss is one of the most common chronic health conditions and has important implications for the patient's quality of life. However, hearing loss is substantially underestimated and under treated.[2] Globally, an estimated 466 million people, corresponding to a prevalence of 6.12% have disabling hearing loss.[3]

The inadvertent injury to the hearing apparatus as a result of persistent exposure to excessive noise with consequent development of Noise Induced Hearing Loss (NIHL) is a well-recognized occupational hazard.[4] NIHL is an irreversible sensorineural hearing loss associated with excessive noise exposure. Worldwide, disabling hearing loss due to occupational noise exposure ranges from 7% to 21%, with about 16% of adult hearing loss being as a result of occupational noise exposure.[3,54] Though one of the most important, permanent hearing loss is not the only adverse health effects of noise exposure. Among the other undesirable effects of noise on health are: annoyance, sleep disturbance, increased risk of accidents, cardiovascular disease and impaired cognitive performance in children.[6,7]

A study in the United States of America by the National Institute for Occupational Health and Safety (NIOSH) demonstrated about 5.7 million workers in the manufacturing industry being exposed to hazardous noise. This figure represents a quarter of the workforce that is exposed to noise.[8] A whopping 96% of workers in an Indian cotton ginning industry exposed to noise levels ranging between 90 -104 dB for over 8hours daily over several years were detected to have hearing loss as compared to 22% among controls tested.[9] The robust mining industry in South Africa is a strong contributor to the country's vibrant economy. Nevertheless, it remains one of the industries contributing to occupational related disorders by way of NIHL. Whilst in 2008, Anglogold Ashanti reported that 77 per 1000 workers were found to have NIHL,[10] a review of data from a platinum mine between 2014 -2017 revealed 64.9% of workers being exposed to noise between 91dBA-

105dBA. 80% of those diagnosed with occupational noise induced hearing loss (ONIHL) were exposed to noise levels up to 104dBA.[11] NIHL is the most compensated occupational (mining) related medical condition in South Africa after occupational lung disease.[10]

Assessment of workers in an Egyptian textile factory demonstrated NIHL in 214 (73.8%) ears of 290 ears assessed. Those with mild sensorineural hearing loss were found to have reduced amplitudes of transient evoked otoacoustic emissions (TEOAE).[12] Again, among workers in a steel rolling factory in Nairobi, 34.2% were found to have NIHL.[13] In the West African sub region, several investigations done in different industries and locations in Nigeria have shown the effect of excessive occupational noise exposure in the causation of permanent sensorineural hearing impairment.[2,14,15] whilst Omokhodion et al (2007) found 56% of small scale mill workers having different ranges of hearing loss[16], Ologe et al(2017) recorded 28.2% of a steel rolling establishment having sensorineural hearing loss as a result of noise exposure.[2]

Not to be spared of this consequence of industrialization, Ghanaian industries, both formal and informal, where workers are exposed to excessive work-related noise have suffered their fair share of this nuisance. Kitcher et al[5], reported the findings of early occupational hearing loss among workers in a stone crashing industry. In this study, 19.3% of the workers in the industry were found with audiometric evidence of early noise induced hearing loss as compared to 1% of controls who were hospital staff. Delving into the informal sector, a section of market mill workers exposed to excessive noise ranging from 85.9dBA - 107. 6dBA over about 8 hours a day for a mean duration of 10.78 years on assessment demonstrated 24.8% of hearing loss as against 2.91% among controls.[17]

Further studies conducted in various noise producing industries which included surface mining, saw mills, printing presses and corn mills have added on to the evidence of sensorineural hearing loss as a result of excessive occupational noise exposure in Ghana.[18,19] Amedofu studied 252 workers in a surface mine in Ghana and demonstrated that 23% had NIHL with the characteristic notch at 4 kHz. Of these, 81 had had pre-employment noise exposure and this group presented a higher incidence (51%) of NIHL than the rest who were not previously exposed to noise.[18] This result differed slightly from earlier work carried out by another group of investigators[20]among underground miners where 20% were found to have been adversely affected with regards to hearing by the high levels of noise in the pits.[20]

Additional work done among stone quarry workers in the Ashanti Region has demonstrated the effect of excessive noise exposure on hearing.[21] Nearly half (of the workers tested had hearing threshold above 25dB with noise exposure levels ranging from 85.5 – 102.7dBA. 2% of the 400 subjects had thresholds as high as 70-90dB signifying severe to profound hearing loss.[21]

1.2 Problem Statement

According to the Veterans Administration of the US Military, NIHL disability costs in the last decade have reached over $1 billion per year.[22] Within the same institution, the Annual Occupational Safety and Health Report to the Secretary of Labour by the Department of the Navy showed that together with other injuries in the Navy and Marine Corps, compensation for hearing loss constituted $234.6M for fiscal year 2011.[23] These are proof of the economic burden imposed by NIHL. Not to mention the effect on quality of life.

Rapid and uncontrolled urbanization in many emerging economies – coupled with a common lack of enforceable regulations on environmental and occupational noise – constitutes a growing source of noise-induced hearing impairment.[24] In the recent past, Ghana has been graduated from a low-income economy to a lower middle-income status.[25,26] This move has been informed by the evident improvement in macro- and micro economic markers with a GDP of $1,363 per capita.[27] There has been an initiative by the present government to establish factories with commercial manufacturing plants across every district in the country. This move of industrialization aimed at improving the socioeconomic status of the country has the potential of contributing to the industrial noise production. As stated by Chi et al, with the booming of infrastructure construction across the world, construction noise together with noise from traffic, society and industry have become the top four sources of noise in the urban environment.[28]

Across the landscape in cities today, active construction work is ongoing with increased activities of real estate developers for both commercial and domestic purposes. All these have necessitated the setting up of many cement block factories to supply the growing demand for this building raw material. These block factories, churning out blocks are a constant source of excessive noise, the levels at which may pose a danger to the hearing of the operators employed in the units as well as nearby people exposed to this hazard.

Though various works have been done in several industries across the country with regards to occupational noise induced hearing loss, there has been no extension of this investigation to include the workers in cement block factory production as well as the noise levels in these factories. Studies have not yet been done to ascertain the actual noise levels at these cement block factories nor has the effect of the noise on the employees in this establishment been confirmed.

Major studies done in Ghana on occupational NIHL so far have employed the use of conventional pure tone audiometry ($_{c}$PTA).[5,17–19] Unspecified audiometry assessment requests are carried out with assessment done for frequencies between 125Hz-8kHz.[29,30] It has been observed decades ago however that noise induced injury occurs and can be observed in higher frequencies before reflecting in the lower frequencies.[31,32] Many current studies have corroborated this phenomenon.[33–35] Extended high frequency audiometric (EHFA) assessment is thus a tool with the capability of detecting NIHL at an earlier stage where interventions can slow or cancel its progression to involve the lower speech frequencies.

There has been a recommendation for the use of the Distortion Product of Otoacoustic Emissions (DPOAE) as a tool for surveillance for noise induced hearing loss. This detects hearing impairment from noise exposure earlier than conventional pure tone audiometry.[17,36–39] This calls for the need to assess the hearing of these workers with both the traditional pure tone audiometry (PTA) as well as the DPOAE to establish this fact among them to enable future surveillance to be carried out by this method. In addition, though numerous works exist as to the presence of hazardous noise in various industries [6, 17-21] both in the formal and informal sectors, there is still no comprehensive data on the extent and levels of noise exposure by economic sector and occupational category.

This necessitated the study in this area to ascertain the noise levels in these industrial settings and the effect on workers' hearing. Establishing a hearing assessment method that is superior in its ability to detect hearing loss earlier than $_{c}$PTA will serve to enhance hearing conservation programs. There is the need to add on to the existing evidence of the effect of occupational noise exposure and the consequent NIHL so that more serious measures are taken in enforcing the existing legislature in this area and if absent, formulation of these bills.

1.3 Rational for the Study

Reports of NIHL in developing countries do not provide comprehensive data on the extent and levels of noise exposure by economic sector and occupational category.[4] In Ghana, hearing assessment by Distortion Product Otoacoustic Emissions and Extended High Frequency Audiometry is sparse even though these have been proposed, and in some circumstances, confirmed to detect hearing deficits earlier than conventional Pure tone Audiometry.[36,37,39]

This research will serve to add on to the growing list of reports on industrial NIHL in Ghana as a country and the Sub-Saharan African Region as a whole to enable computation of this necessary comprehensive data in our population. It will also provide hearing loss prevalence as assessed by EHFA and DPOAE which are known to detect hearing loss earlier than conventional PTA (cPTA).

With all the above, there will be strengthening of the evidence that will push the need for strict enforcement of the existing laws governing the prevention of noise induced sensorineural hearing loss. Institution of frequent monitoring using methods likely to detect adverse changes to the ear earlier will be advocated for.[40,41]

1.4 Aim and Objectives

1.4.1 Aim

The study aimed to determine the prevalence of NIHL among the workers and compare the differences between measurements by PTA (including EHF) and DPOAE.

1.4.2 Specific Objectives

1. To assess the level of awareness of the effect of noise on hearing, availability of hearing protective devices and their use among the block factory workers.

2. To assess the noise levels in the selected block factories

3. To assess the hearing threshold of subjects by pure tone audiometry: both conventional and EHF and DPOAE amplitudes

4. To determine the differences in the ability of each method to capture hearing impairment.

1.4.3 Null Hypothesis

There will be no difference in the prevalence of noise induced hearing loss among cement block factory workers as measured by Pure Tone Audiometry (conventional and extended high frequency) and Distortion Product Otoacoustic Emissions.

1.4.4 Alternative Hypothesis

Distortion product otoacoustic (DPOAE) emissions can produce significantly higher prevalence of noise induced hearing loss than conventional and Extended High Frequency Pure Tone Audiometry among cement block factory workers.

CHAPTER TWO

LITERATURE REVIEW

2.1.1The Hearing Mechanism

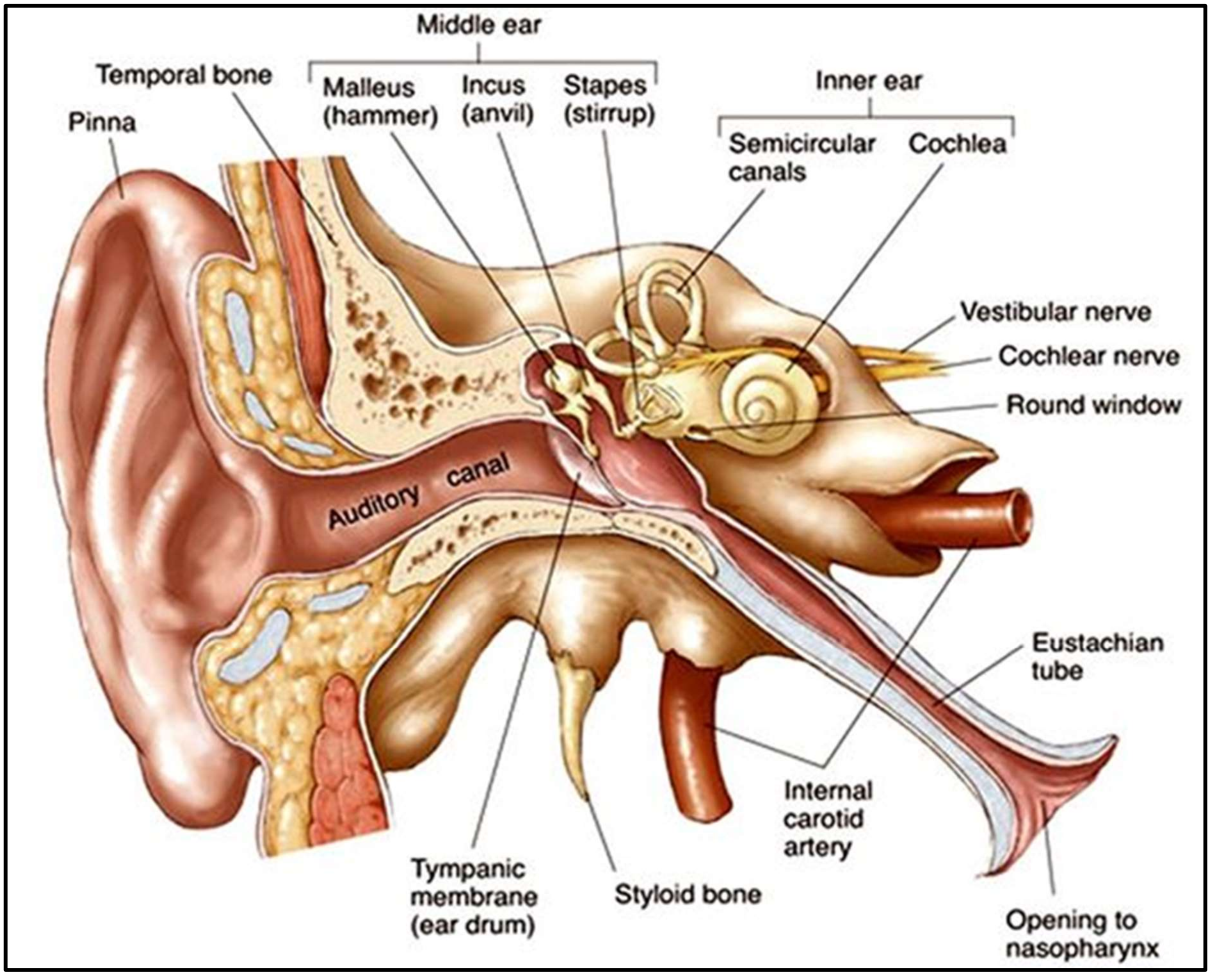


Figure 2.1: Anatomy of the ear

Source: @ClinAnat.OperSurg · Health & Wellness Website

The ear is the organ of hearing and balance. It consists of:

- the outer ear
- the middle ear and
- the inner ear

The outer ear is made up of the pinna or auricle and the external auditory canal.

The tympanic membrane separates the external from the middle ear and is functionally a part of the middle ear. The middle ear or tympanic cavity lies between the tympanic membrane laterally and the cochlear apparatus medially. It is lined by a mucous membrane and filled with air. Together with the Eustachian tube and the aditus leading posteriorly into the mastoid antrum and air cells, they form the middle ear cleft. (The Eustachian tube leads anteriorly to the nasopharynx. It is the conduit for aeration of the middle ear cleft). It is a six-sided cavity divided into a superior epitympanum, middle mesotympanum and inferior hypotympanum.[36] The lateral wall is formed mainly by the tympanic membrane and the outer bony wall of the epitympanic recess superiorly. The medial wall is also the lateral wall of the inner ear and presents two windows – the upper oval window (fenestra vestibuli)- the lower round window (fenestrae cochleae) covered by the secondary tympanic membrane. In front of and between these two windows lies the promontory which is formed by the basal turn of the cochlea. The processus cochleariformis, containing the tendon of the tensor tympani, is situated on the anterior and superior part of the medial wall in front of the point of entry of the facial nerve from the inner ear.[43]

The middle ear cavity houses three small bones – the ossicles. These are:

- the malleus
- the incus
- the stapes.

Supported by ligaments, they form an articulated connection between the tympanic membrane laterally and the oval window medially. The malleus consists of a head, neck, anterior and lateral processes and a handle which is attached to the drumhead. The head is situated in the attic articulating with the body of the incus, the short process of which has a ligamentous attachment to the floor of the aditus. The long process of the incus extends downwards and its lentiform process articulates with the head of the stapes. The stapes, so called because of its stirrup-shaped appearance, has a head, a neck, two crura or limbs, and a footplate which is fixed to the margins of the oval window by an annular ligament.[42] The tensor tympani muscle which arises from the auditory tube, the adjacent part of the greater wing of the sphenoid and the bony canal in which it lies inserts into the medial surface of the malleus near the neck. Its action is to tense the tympanic membrane by drawing it medially. The tendon of the stapedius on the other hand inserts into the neck of the stapes and acts to dampen the movement of the stapes by tilting outwards the anterior end of the footplate.[43]

The inner ear lies within the petrous part of the temporal bone. It consists of a membranous labyrinth enclosed in a bony labyrinth. The membranous labyrinth contains fluid - the endolymph, and the space between the bony and the membranous labyrinth also contains fluid - the perilymph. The bony labyrinth consists of the vestibule, three semicircular canals and the cochlea. The bony cochlea contains three compartments:

- scala vestibuli
- scala tympani,
- scala media or the membranous cochlea.

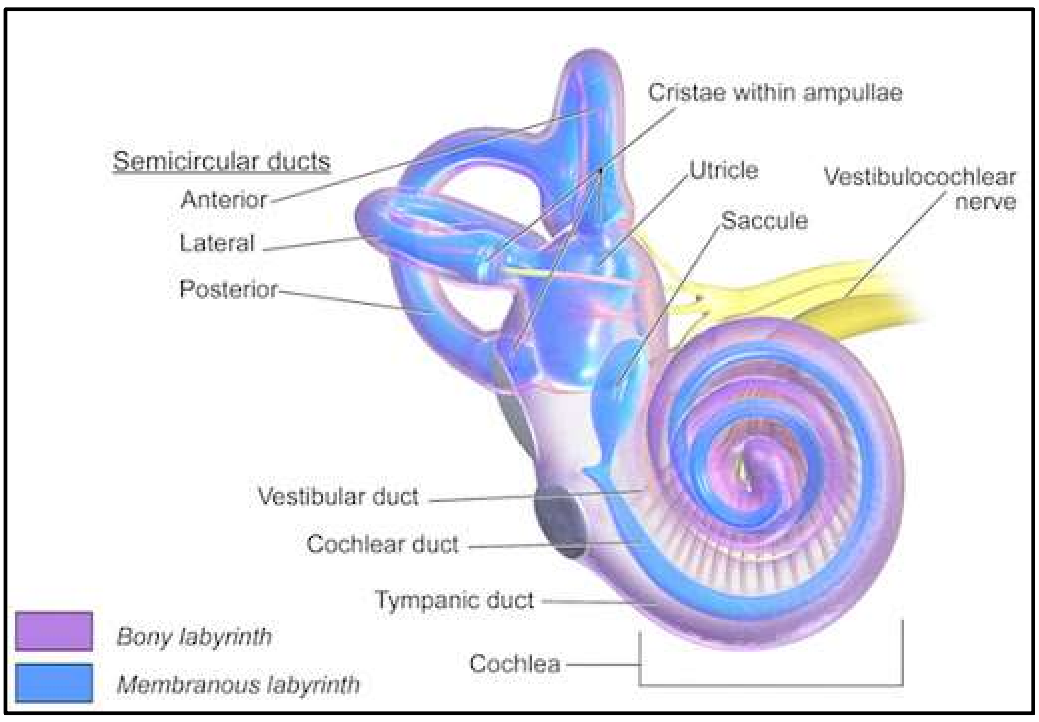


Figure 2.2 The bony and membranous labyrinth of the inner ear

Source: Sound: An interactive e-book.

The scala vestibuli and scala tympani are filled with perilymph and communicate with each other at the apex of cochlea through an opening - the helicotrema. Scala vestibuli is closed off by the stapes footplate which separates it from the air-filled middle ear. The scala tympani is closed by the secondary tympanic membrane; it is also connected with the subarachnoid space through the aqueduct of the cochlea.[43]

The membranous labyrinth consists of:

- the cochlear duct, the utricle and saccule,
- the three semicircular ducts, [44]
- the endolymphatic duct and sac.

The cochlear duct (membranous cochlea or the scala media) is a blind coiled tube which appears triangular in cross-section and its three walls are formed by:

- the basilar membrane, which supports the organ of Corti,
- the Reissner's membrane which separates it from the scala vestibuli,
- the stria vascularis, which contains vascular epithelium and is concerned with secretion of endolymph

The length of basilar membrane increases as we proceed from the basal coil to the apical coil. It is for this reason that higher frequencies of sound are heard at the basal coil while lower ones are heard at the apical coil.[43]

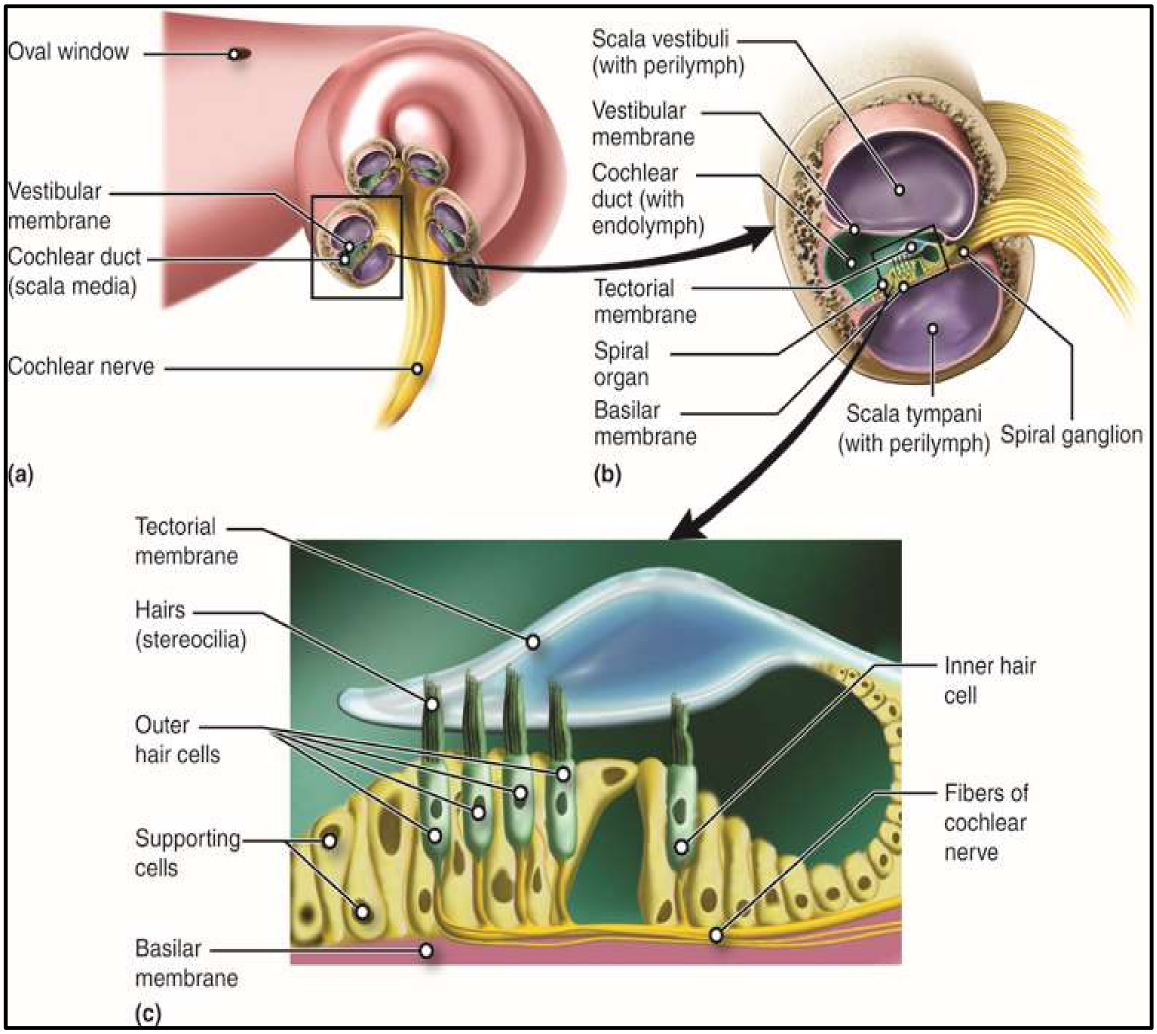


Figure 2.3: Anatomy of the cochlea

Anatomy of the Cochlea. The cochlea is a spiral structure (a) divided into three chambers (b). The middle chamber, the cochlear duct, contains the spiral organ that has hair cells (c) for sensing the vibrations we perceive as sound. This work by Cenveo is licensed under a Creative Commons Attribution 3.0 United States

Source: http://creativecommons.org/licenses/by/3.0/us/.

2.1.2 The Auditory System and the Hearing Mechanism

The Organ of Corti is the organ for hearing. Lying on the basilar membrane, it consists of:

- the outer and inner rows of hair cells
- the supporting cells
- the tectorial membrane which overlies the hair and supporting cells and produces a stimulus by a shearing force between it and the hair cells
- the tunnel of Corti which is found between the inner and outer rows of hair cells.[43]

The hair cells are the receptor cells for hearing and transduce sound energy into electrical impulses which are transmitted by nerves to the brain. Inner hair cells form a single row while outer hair cells are arranged in three or four rows. Inner hair cells are richly supplied by afferent cochlear fibres and are the main structure in the transmission of auditory impulses. Outer hair cells mainly receive efferent innervation from the olivary complex and are concerned with modulating the function of inner hair cells. Ninety-five percent of afferent fibres of spiral ganglion supply the inner hair cells while 5% supply the outer hair cells. Efferent fibres to the hair cells come from the olivocochlear bundle. Their cell bodies are situated in the superior olivary complex. Each cochlea sends innervation to both sides of the brain. Hair cells are innervated by dendrites of bipolar cells of the spiral ganglion situated in Rosenthal's canal (canal running along the osseous spiral lamina). Axons of these bipolar cells form the cochlear division of CN VIII and end in the cochlear nuclei, the dorsal and ventral, on each side of the medulla.[38]

Further course of auditory pathways is complex. From cochlear nuclei, the main nuclei in the ascending auditory pathways, sequentially from below upwards is:

(a) Superior olivary complex

(b) Nucleus of lateral lemniscus

(c) Inferior colliculus

(d) Medial geniculate body

(e) Auditory cortex.

The auditory fibers travel via the ipsilateral and contralateral routes and have multiple decussation points. Each ear is therefore represented on each side of the cerebral hemisphere. The area of cortex, concerned with hearing is situated in the superior temporal gyrus (Brodmann's area 41). [44]

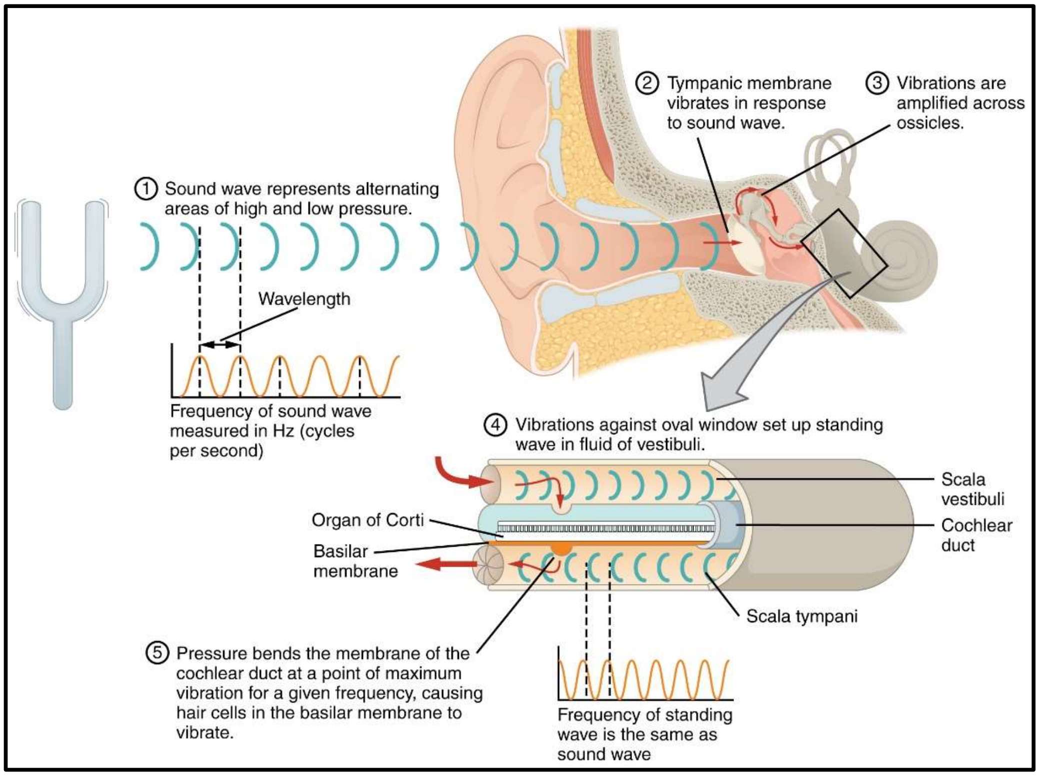


Figure 2.4: Transmission of sound waves to the cochlea

Source: https://open.oregonstate.education/aandp/chapter/15-3-hearing

Sound is produced when objects vibrate, causing waves of compression and rarefactions. These waves are collected by the pinna and directed into the external auditory meatus, striking the tympanic membrane. This causes the drumhead to vibrate, transmitting the sound through the ossicles to the oval window. Movements of the stapes footplate cause pressure changes in the perilymph which move the basilar membrane. This stimulates the hair cells of the organ of Corti. It is these hair cells which act as transducers and convert the mechanical energy into electrical impulses which travel along the auditory nerve to the various sections of the auditory pathway and finally to the auditory cortex. Inherent anatomic and physiologic properties of the external and middle ear allow certain frequencies of sound to pass more easily to the inner ear due to their natural resonances.

Thus, greatest sensitivity of the sound transmission is between 500 and 3000 Hz and these are the frequencies most important to man in day-to-day conversation. In addition, higher frequencies are represented in the basal turn of the cochlea and the progressively lower ones towards the apex.

There are four types of electrical potentials recorded from the cochlear and the vestibulocochlear nerve (CN VIII):

- Endocochlear potential
- Cochlear microphonic
- Summating potential
- Compound action potential - from nerve fibres

The first three potentials are from the cochlear. The endocochlear potential is a direct current (DC) potential recorded from the scala media. It is +80 mV and is generated from the stria vascularis by Na^{+} /K^{+} ATPase pump and provides a source of energy for cochlear transduction. It is present at rest and does not require a sound stimulus.[44]

The Cochlear microphonic (CM) is produced when basilar membrane moves in response to sound stimulus. This causes changes of electrical resistance at the tips of hair cells allowing flow of K^{+} through hair cells and produces voltage fluctuations called cochlear microphonic. It is an alternating current (AC) potential. Summating potential (SP) is a DC potential and follows sound stimulation. It is produced by hair cells. It may be negative or positive. It is superimposed on VIII nerve action potential. The compound action potential is an all or none response of auditory nerve fibers.[45]

2.1.3 Some Attributes of Sound

Frequency – The number of cycles per second of the sound wave, measured in Hertz. The human ear can perceive frequencies from 20Hz to 20kHertz. The speech frequency ranges from 500 to 2000Hz. The subjective sensation of frequency is the **Pitch.** The pitch is directly proportional to the frequency.

Pure Tone – Sound is classified as pure tone when it consists of only one particular frequency.

Complex Sound – Any sound consisting of more than one frequency e.g., human voice

Intensity – the attribute of sound that determines its loudness. It is measured in decibels. Sound can also be measured as **power in watts/cm^2** or as **pressure in dynes/cm^2.** In audiology sound is measured as Sound Pressure Level **(SPL).** It is comparable to the reference sound which corresponds to the threshold of hearing in normal subjects at 1000Hz

Masking – the phenomenon to produce inaudibility of one sound by the presentation of another. Masking of non-test ear is essential in all bone conduction tests, but for air conduction tests, it is required only when difference of hearing between two ears exceeds 40 dB

Threshold of hearing – The minimum level at which a signal can be detected.

The Sound Level Meter - It is an instrument to measure level of noise and other sounds. Sound level meters have different weighting networks (e.g., A, B or C) for different sensitivities at different frequencies. When describing a sound measured by a sound level meter, the weighting network must be indicated. Noise levels are often expressed as dB(A) which refers to sound pressure level measured with "A" network where the low and extremely high frequencies are given much less weightage compared to those in the middle range which are more important and are responsible for noise-induced hearing loss.

2.1.4 Noise Induced Hearing Loss (NIHL)

This describes the reduction in a person's hearing ability as a result of excessive noise exposure.[46] It may be temporary, in which case it is called a temporary threshold shift(TTS); or it may be permanent, when it is referred to as a permanent threshold shift(PTS).[47] Sources of noise responsible for NIHL are varied and may be occupational or recreational.[46]Of rising concern among young people is the use of personal listening devices leading to excessive noise exposure.[48] Throughout the world, industrial noise exposure remains one of the most important sources of hearing health impairment which may be preventable.

Pathophysiological basis of noise induced hearing loss involves cochlear damage. Whereas metabolic mechanisms are considered to be responsible for TTS[49], PTS is thought to be as a result of structural changes within the cochlear microstructure.[50]

Noise induced hearing loss, especially of occupational causes is a diagnosis with both clinical and medicolegal implications and its diagnosis must be carefully made with all available factors taken into consideration.[46]

2.2 Hearing Threshold Assessment

Hearing threshold assessment is done by clinical (bedside) and audiometric methods. The audiometric approaches could be behavioural or electrophysiological. Clinical assessment methods include Clinical Voice Testing and the several methods of Tuning Fork tests (e.g., Rinne and Weber tests). These bedside tests are a basic screening tool for hearing loss.[30]

Audiometric methods include:

- Pure Tone Audiometry
- Speech Audiometry
- Bekesy Audiometry

These are behavioural tests.

Among the electrophysiological methods are:

- Electrocochleography
- Auditory Brainstem Response
- Otoacoustic Emissions

Additional important hearing assessment methods include:

- Recruitment Tests
- Short Increment Sensitivity Index (SISI)
- Threshold Tone Decay Test
- Central Auditory Test

2.2.1 Pure Tone Audiometry

This is the main method for assessment of hearing impairment.[1] It is the basic audiometric test and assesses the threshold for air and bone conduction over a range of pure tones for each ear. It is useful in the determination of hearing impairment and the type – sensorineural, conductive or mixed.[1]

Performed ideally in a sound treated room, a calibrated audiometer is used. The acceptable maximum noise level in the sound treated room should not exceed 35dB(A). The examiner should be able to see the patient at every point in time to quickly detect when patient is uncomfortable, confused or has lost focus. The patient however should not see nor hear the examiner manipulating the equipment. The examiner and the patient should be able to communicate verbally however and an intercom serves to carry out this purpose.[29]

The hearing threshold over standardized frequencies are determined for both air and bone conduction and plotted graphically to obtain an audiogram. In assessing the threshold for air conduction, sound is presented to each ear by insert earphones or headphones and by this, the whole auditory pathway is evaluated.[30] In the determination of the hearing threshold at the various frequencies, the subjects are positioned in the sound treated room where instructions are given as to how the procedure is undertaken. The better hearing ear (if any) assessed first. Subjects are provided with the insert ear phones or headphones through which the tones are presented (between 1-3 seconds) and they are to indicate at the faintest tone heard no matter how faint. A familiarization tone is presented at greater than or equal to 30dB and if not heard, increased in steps of 20dB till subject perceives the sound whilst observing his demeanour and manner of response.

The frequencies are tested in the order: 1,2 (3), 4, (6),8,0.5,0.25 then 1 kHz again. For the second ear, there is no repetition at 1kHz. At each frequency a tone above the suspected threshold is started with and reduced in 10dB steps till no longer heard. The tone intensity is then increased in 5dB steps till perceived again. This procedure is repeated till the intensity where the tone can be perceived at least 50% of the time when ascending and this will be recorded as the threshold for that particular frequency. This is known as the bracketing technique or 10dB down, 5dB up technique .[29]

In bone conduction threshold determination, the cochlear is stimulated directly by placing a bone vibrator on the mastoid and directly assessing the sensory-neural portion of the hearing mechanism. Introduction of a distracting noise to one ear is done in some instances to eliminate the chances of the better hearing ear being tested rather than the poor ear which is being presented with the sound. This is the masking process done when there is a difference of 40dB or more between the two ears at a particular frequency during air conduction testing.

The results of pure tone audiometry are recorded on an audiogram. This is a graph with the test frequencies on the horizontal (x) axis measured in Hertz and the sound level on the vertical (y) axis in decibel hearing levels (dBHL). The frequencies range from 125Hz to 8kHz and the sound level from -10 to 120dBHL. Frequencies are usually tested at octave intervals – i.e., 125 – 250 – 500 – 1000 – 2000 – 4000 – 8000 Hz. The inter-octave frequencies (.75,1.5,3,6 kHz) are tested when the threshold between two consecutive octave frequencies differ by 20dB or more or when the desired frequency resolution is higher – for example, when testing for hearing aids. Different symbols and colour coding are used to record obtained thresholds for each ear and transducer used. This is institution dependent and a key is usually produced on the audiogram for interpretation.

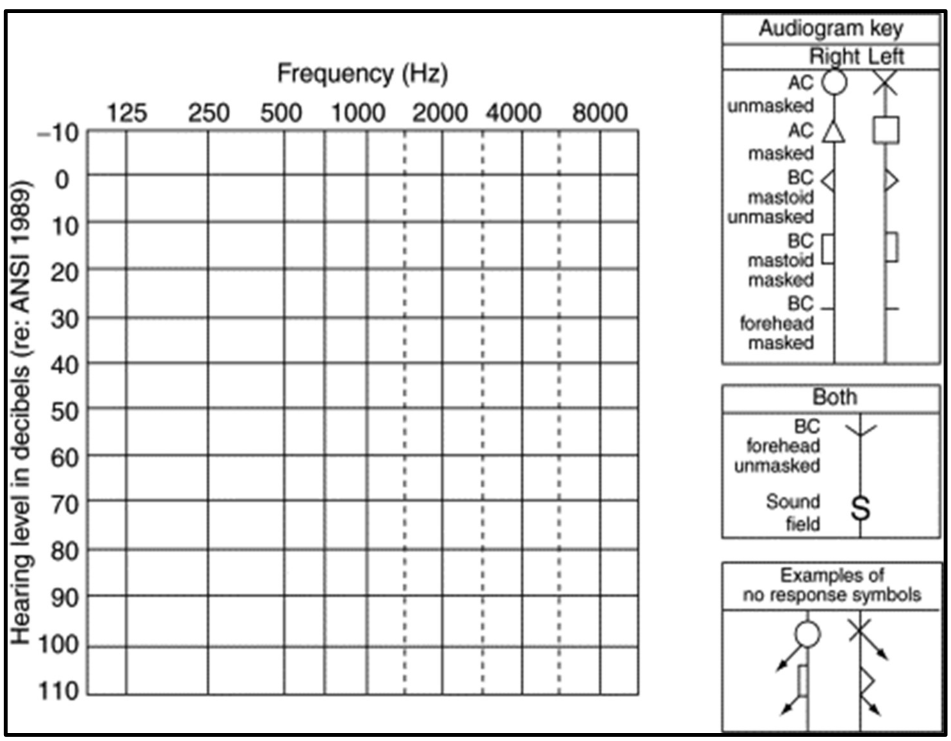


Figure 2.5: An audiograph

Source: omicron.wiserhosting.co.uk

Once the threshold for the different frequencies have been determined, the average of the threshold for 500, 1000, 2000 and 4000Hz is calculated and this gives the Pure Tone Average (PTA) (Browning, 2001).[1] For some specific occasions, a three - frequency average is calculated, using the thresholds at 500, 1000 and 3000Hz (e.g. when assessing for compensation for occupational NIHL in the United Kingdom.). When the main interest is in noise induced hearing loss, PTAs may be calculated at 2000, 3000,and 4000Hz[5] or at 3000,4000 and 6000 Hz [51,52] because of lack of sensitivity of noise exposure at 500 and 1000Hz.[5,17]

Features on audiograms that typify NIHL are hearing thresholds high in the high frequencies and audiometric notches, usually at 4kHz, but could also be at 3 or 6kHz. An audiometric notch as defined by Coles is hearing thresholds at 3 or 4 or 6 kHz of 10 dB or more compared with that at 1 or 2 kHz and 6 or 8 kHz. The criteria established by Coles et al. have been proven to correlate well with clinical assessments.[53]

The World Health Organization [54](Olusanya, Hearing Loss Grades,2019) grades hearing loss into:

- Normal: ≤ 25dBHL
- Mild: 26 – 40 dBHL
- Moderate: 41 – 60 dBHL
- Severe: 61-80 dBHL
- Profound: >80 dBHL

Disabling hearing loss is hearing levels of 40dB or more in the better hearing ear for an adult, or for a child, >30dB.

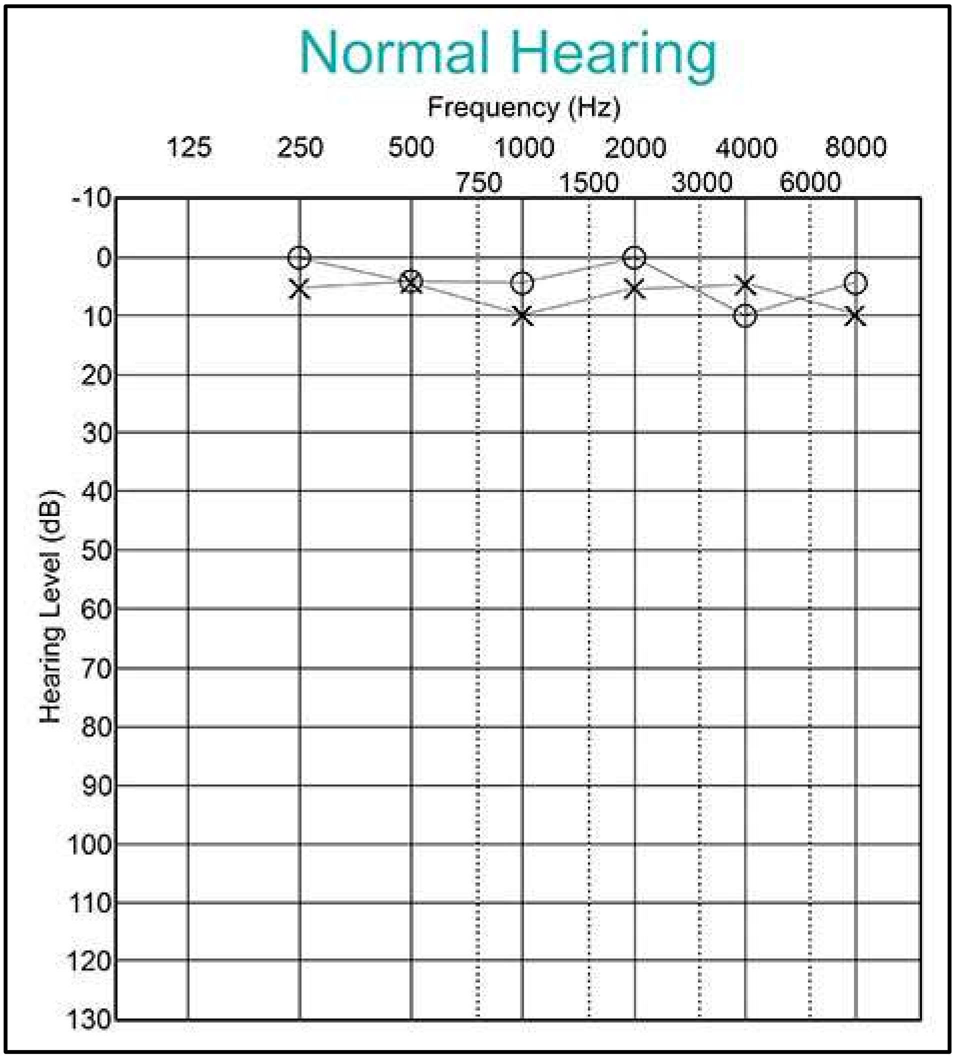


Figure 2.6: Audiogram demonstrating normal hearing thresholds bilaterally

Source: www.Babyhearing .org

An audiogram demonstrates conductive hearing loss when the air conduction threshold is higher than 25dB but the bone conduction threshold is within normal limits with an air- bone gap greater than 10dB.[1] Some authors have quoted a gap of 15dB or greater being the gap needed to state an air-bone gap.[55]

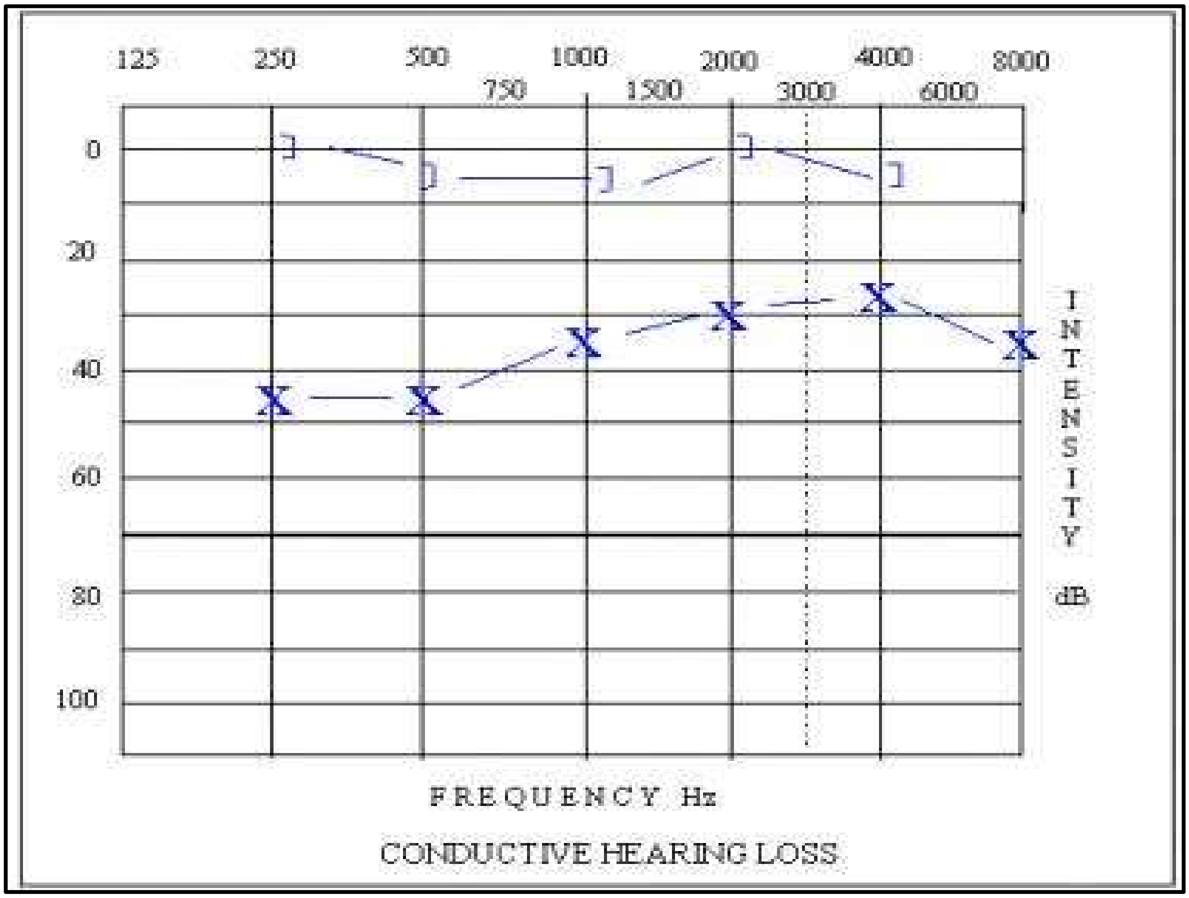


Figure 2.7: An audiogram showing left conductive hearing loss

Source: entpa.org

In sensorineural hearing loss, the audiogram shows both air conduction and bone conduction thresholds greater than 25dB but within 10dB of each other.

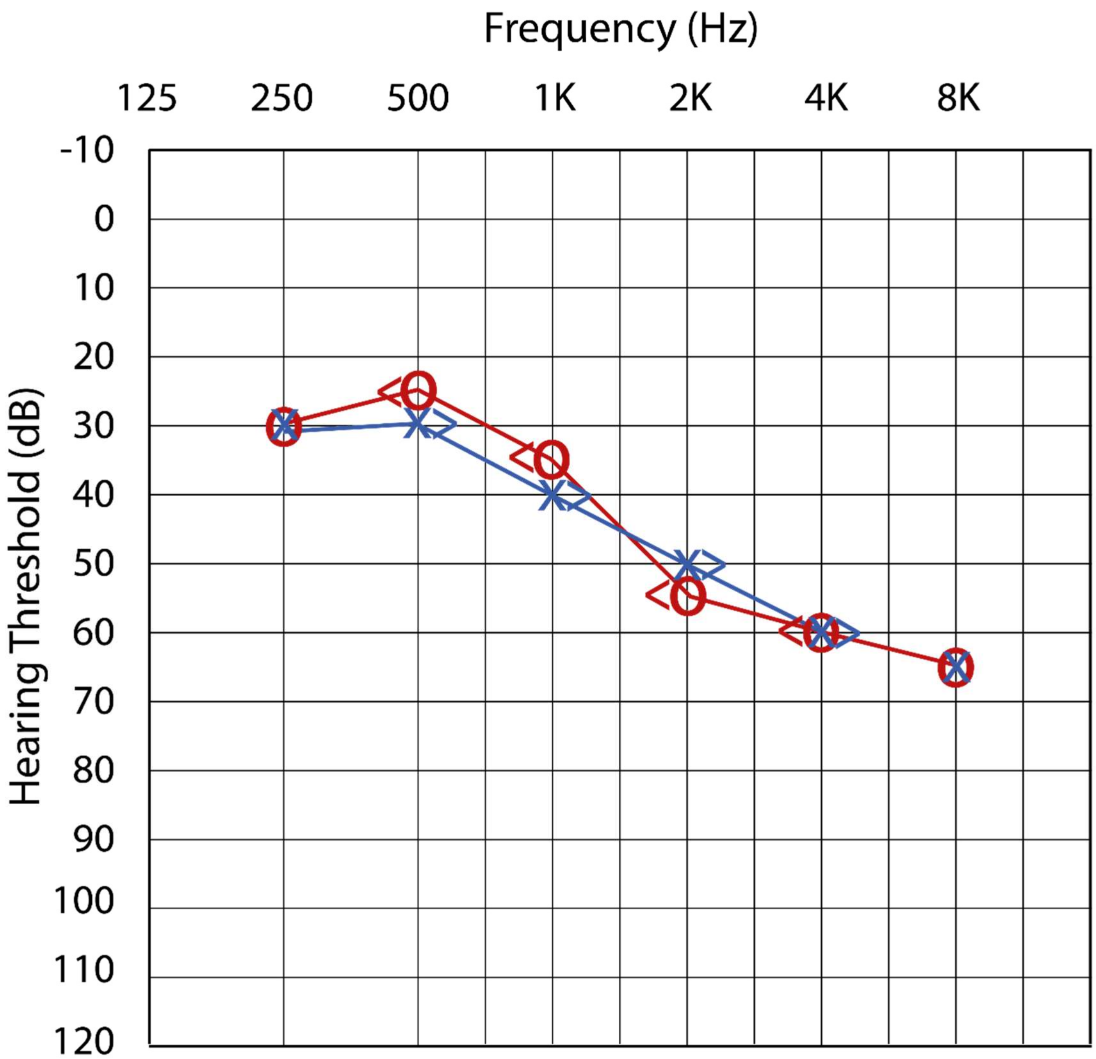


Figure 2.8: Audiogram showing bilateral sensorineural hearing loss

Source: entpa.org

Mixed hearing loss is shown by both air conduction and bone conduction threshold being greater than 25dB but with an air-bone gap of greater than 10dB.

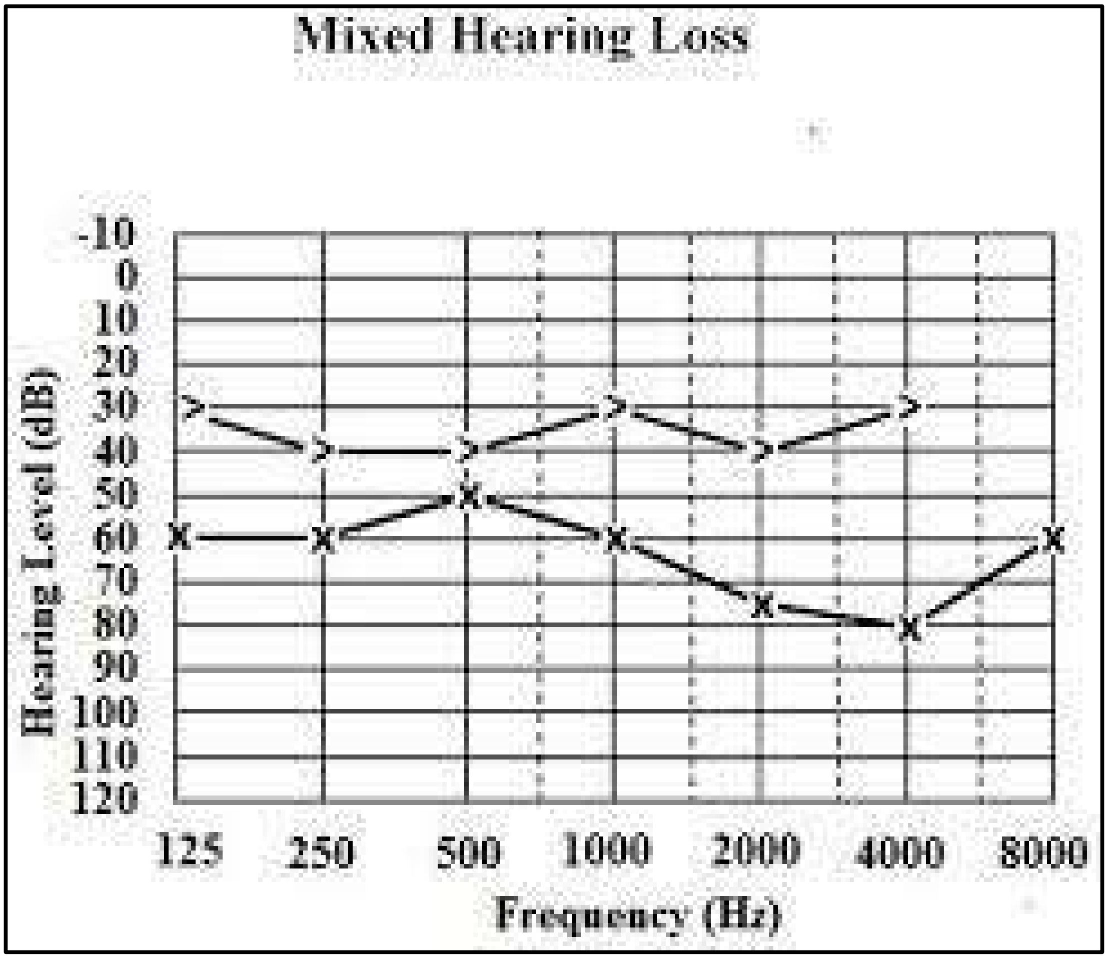


Figure 2.9: Audiogram demonstrating left mixed hearing loss

Source: dhheducation.weebly.com

2.2.2 Extended High Frequency Pure Tone Audiometry (EHFPTA)

Without specification, a request for a patient to have PTA assessment involves testing of thresholds for frequencies up to 8000Hz as described above. This is conventional or standard PTA. It has long been known that the human ear is able to perceive sounds of frequency ranging between 20Hz to 20kHz [29,30,56] even though the conventional audiometry only tests up to 8kHz.[29,30,56] Frequencies above this- particularly from 9kHz to 20kHz have been labelled as Extended High Frequency (EHF) or ultra-audiometric range of hearing.[35,56,57]

Over several decades it has been known that elevated thresholds in the EHF range have been associated with NIHL.[58]and ototoxic drug use.[31,59–61]In recent times more evidence has been gathered in support of this. A study of 12 individuals with varied history and exposures examined with both conventional and EHF audiometry showed that though the former showed normal threshold values, all the subjects had thresholds higher than the 95 percentile for their age especially from 9000Hz and above indicating the ability of EHF audiometry to identify hearing impairment where the conventional method shows normal findings.[57]

When Kumar et al[35] studied a group of 100 young people, 70 of whom regularly used personal listening devices (PLD) and 30 non-users he found statistically significant differences in the mean threshold between the groups from 3000Hz and above to 16kHz. Among users, the group with more than 5- year use had significantly higher thresholds at the frequencies 10kHz to 13kHz and those who used the devices at higher volumes had significantly higher thresholds than those with lower volume use or non-users. They concluded that EHF could be used in the early detection of sensorineural hearing loss from the noise exposure of PLD use and this could thus be used as a screening tool and help prevent progression to a permanent loss[35]

This finding was similar to that of Sulaiman et al[34] who studied 35 PLD users and controls using conventional PTA, EHFA TEOAEs and DPOAEs. On conventional PTA, there were no signs of NIHL and thresholds were similar to that of controls. However, thresholds at the EHF were significantly raised and TEOAE and DPOAE amplitudes were reduced among subjects as compared to controls.[34] Recreational firearm use is a source of noise with the consequences of producing NIHL. This was investigated among a group of 11-17-year-old youth of Michigan using conventional PTA, EHFA and DPOAEs. Results showed increased thresholds both for the conventional frequencies as well as the high frequencies with no statistical difference between the two methods.[62]

2.2.3 Otoacoustic Emissions

The outer hair cells of a normal cochlear produce low intensity sound that can be detected by microphones placed within the external auditory canal[29]These sounds produced by healthy cochlea travel in a reverse pathway to the basilar membrane to the perilymph and transmitted thence to the oval window. The ossicular chain picks up the vibrations and transmits these to the tympanic membrane from where external auditory canal microphones detect them. A damaged cochlea is unable to produce otoacoustic emissions.[29]

OAEs are produced spontaneously but can be elicited by the presentation of sound to the cochlea. The latter are referred to as evoked OAEs. Evoked OAEs are further grouped into Transient Evoked OAEs (TEOAEs) (elicited by presenting clicks at 80 – 85 dBs and) and Distortion Product OAEs (DPOAEs) (evoked by simultaneous presentation of two tones to the cochlea and recording the distortion product). Clinically, OAEs are used for:

- Newborn hearing screening
- Uncooperative mentally challenged individuals
- Distinguish between cochlea and retro cochlear lesions

Otoacoustic emissions (OAEs) permit the early detection of inner ear abnormalities that are associated with a wide variety of diseases and disorders, including non-pathologic etiologies, such as noise exposure and aging. Changes in outer hair cell length generate energy within the cochlea that contributes to hearing sensitivity and the ability to distinguish small differences in the frequencies of sounds.[63] In 2001, Attias et al[64] reported on a study which set out to explore the application of OAEs in the earlier detection of noise induced hearing loss among soldiers in Israel as compared to conventional PTA. They applied Click evoked OAEs (CEOAES) and DPOAEs to both noise exposed subjects as well as subjects with no prior noise exposure. Their findings established a clear association between OAEs and the severity of NHIL. They noted that as the severity of NHIL increased, the emission range of the OAEs became narrower and the amplitude smaller. They therefore concluded that OAEs were more sensitive to noise damage than behavioural audiometry and hence a more objective and accurate tool to detect and monitor the status of the noise exposed cochlear.[64]

A publication by Oeken et al (2000) that presented the results of a study to assess the influence of age and presbyacusis on DPOAE demonstrated a highly significant decrease in amplitude of DPOAE and hence of inner ear function. This correlated well with deterioration in pure- tone threshold.[65] As noted by Feder et al in their study among working Canadians, audiometry is traditionally used to monitor hearing in industrial workplaces; however, distortion product otoacoustic emissions (DPOAE) testing has received attention as a promising hearing surveillance tool and a potential adjunct to the audiogram in the diagnosis and monitoring of occupational NIHL. They further stated that DPOAEs are able to detect earlier the subtle cochlear changes especially with regards to the outer hair cells after exposure to excessive noise making way for earlier detection of NIHL as compared to the use of conventional audiometry.[37]

Hall and Lutman (2000) studied the reliability of various methods of hearing loss assessment using three methods of OAE and PTA. They concluded that the methods using OAEs – TEOAE, TEOAE maximum length sequences (TEOAE-MLS) and DPOAE – had potential for detecting small changes in cochlea function and had promise for monitoring of ears exposed to noise and other hazards.[66] In the investigation of a group of young men for the early detection of noise induced hearing loss, Bozzato et al found that though conventional PTA and TEOAE were unable to detect any deficit, high frequency DPOAE and EHFPTA revealed findings suggestive of noise induced injury.[36] They concluded that objective measurement of DPOAE had the potential for the detection of sensorineural impairment when conventional PTA indicated none.

After treatment of head and neck tumours by radiotherapy, a cohort of patients were assessed for sensorineural hearing loss by PTA and DPOAEs. Evaluation was done pretreatment, a month after and twelve months after. Although no SNHL was found after the first month by PTA, 47% of subjects, showed hearing loss on assessment in the twelfth month. On the other hand, DPOAE demonstrated statistically significant lower amplitudes in the first month post treatment.[38] A study of the components of OAEs evoked by DPOAEs carried out by Prieve et al observed a reduction in the fine structure, generator and reflection components of the OAEs in ears with hearing loss as compared to ears with normal hearing thresholds[67].

Some studies however have not been in full support of this idea of the ability of DPOAEs to detect NHIL earlier than traditional PTA. For example, a group of 30 young individuals with a noise exposure background and normal hearing were assessed by ABR and DPOAEs to identify any indications alluding to the previous noise exposure. Although amplitude of wave I of the ABR was inversely proportional to level of calculated noise exposure, there was no significant difference in DPOAEs between individuals no matter their level of noise exposure background.[68]

This had been corroborated in an earlier study in noise exposed mice where significant neuronal degeneration with synaptic injury noted in the cochlear was not matched by a change in outer hair cell population and consequently, of DPOAEs after two weeks of the exposure although decrements in amplitude had been observed after 24 hours of exposure from preexposure values.[69] Similar results were found when the study was replicated in guinea pigs, demonstrating further that though wave I of ABR was able to detect long term synaptopathy and neuropathy, ABR and DPOAE thresholds remained unchanged, unable to detect the noise induced microscopic injury.[70]

A retrospective study of PTA and DPOAEs of 16 brickyard workers in the United Kingdom with varying durations of occupational noise exposure did not find correlating low OAE amplitudes at frequencies with increased hearing threshold and therefore concluded that the advocacy for the use of DPOAEs as a screening tool for occupational NIHL lacked firm grounding.[71] On the other hand, 285 Marine Corps recruits who had audiometric threshold and otoacoustic emissions measured found that of the subgroup of 60 who were noise exposed and met the criteria for assessment post exposure, amplitudes of OAEs were reduced significantly after 3 weeks of firearm noise exposure whereas the audiometric thresholds were largely unchanged as compared to controls. Both TEOAEs and DPOAEs were measured and were found to be reduced in amplitude .[72]

2.3 Excessive Noise Exposure and Noise Induced Hearing Loss

Noise is any unpleasant, irregular, confusing and disharmonic sound.[73] Probably the most widespread nuisance, it is a recognized health hazard with known physical and psychological impacts on the individual.[74] Undoubtedly, chronic noise exposure leads to cochlear trauma with consequent hearing loss and tinnitus.[75] Noise induced hearing impairment; the most prevalent occupational hazard remains the most readily recognized noise associated health effect.[76] Other less commonly appreciated but pertinent unwanted effect of noise exposure includes: interference with speech communication; disturbance of rest and sleep; mental health and performance effects; effects on residential behaviour and annoyance and interference with intended activities .[76]

Noise induced hearing loss is a reduction in hearing acuity as a result of excessive noise exposure. This loss may be temporary – when it is referred to as temporary threshold shift (TTS) - or it may be permanent – permanent threshold shift (PTS).[46] On some occasions, a single intense sound exposure (over 140dBA) leads to sudden hearing loss and this is referred to as acoustic trauma .[73] The likelihood of sound levels below 80dB(A) to cause harm is low, even over prolonged exposure whereas at or over 130dB(A) exposure over even minimal time periods tends to be damaging to the human ear. Thus, above 80dB (A), the safe period of exposure to noise decreases as the intensity increases. This thinking has been quantified with the concepts of noise immision level (NIL) and the equal energy hypothesis.[46,75,77]

The cochlear mainly bears the brunt of noise induced hearing damage. Pathological changes could be metabolic or structural. Metabolic changes noted include increased release of neurotransmitters, changes in cochlear blood flow and cochlear hypoxia. Structural changes observed are outer hair cell death (OHC) or non-function of the remaining ones after exposure to noise. Another adverse effect of excessive noise exposure termed synaptopathy is the damage to the synaptic connections of the inner hair cell to the spiral ganglion cells. All these effects are not mutually exclusive, but work in a complex related manner to result in NHIL.[69]

Though SNHL results from prolonged noise exposure as described above it is not the only means by which hearing loss develops as a consequence of noise exposure. Sudden intense noise around 100 – 140dB(A) for example as from a gunshot can cause rupture of the tympanic membrane with ossicular chain dissociation with or without inner ear damage leading to conductive or mixed hearing loss [78,79].

A cross sectional study carried out on 221 members of the Kuwaiti Air Force showed 14.8% of them with NIHL. Hearing loss was mainly in the high frequencies and was of mild and moderate degree. Those pilots aged over 40 years as well as those with more than 1000 flying hours had average thresholds greater than the mean threshold.[80] It is noteworthy that of those with the NIHL, most were found in the high frequency range of 4000-6000Hz – the frequencies usually involved in this disease entity.[80]

Though NHIL has been extensively researched in various industrial settings, noise exposure occurs within some occupational settings covertly and these 'hidden' avenues are yet to obtain attention as the industrial ones. In this regard, officers of the Royal Brunei Police Force (RBPF) in Brunei Darusssalam were investigated. Of the 365 personnel eligible for the study, 34.2% were found to have NHIL with males having a higher prevalence (37.7%) than females (23.9%). Those officers with the longest duration of service tended to have the highest prevalence (50.5% for males;72.7% for females). Of those identified to have the hearing loss, majority (93%) had mild NHIL, 3.5% and another 3.5% had severe hearing loss. None was found to have profound hearing loss. Identified sources of noise exposure for these personnel were shooting practice, police motorcycling and traffic policing.[81] Studies among the French police officers, and the traffic police in Kathmandu City, Pune and Jalgaon (both in India) have all demonstrated an increased prevalence of NHIL with a prevalence as high as 84% among the Jalgoan subjects.[82,83]

An estimation of the incidence and trends of occupational diseases among Dutch construction workers found noise induced hearing loss (8125 per 100 000 population) and musculoskeletal disorders to be the most frequently reported with NHIL together with contact dermatitis showing an increasing prevalence.[84] In India, a cohort of Delhi construction workers investigated found 40% of the 451 workers with various degrees of hearing loss assessed by audiometry.[85]

It is noteworthy to mention that as reported by Azizi (2010), the presence of rheumatoid arthritis and diabetes mellitus further increases a person's risk of developing noise induced hearing loss when exposed.[86]

2.4 Noise Levels in Industries

In the United Kingdom and the United States of America, the industrial guidelines allow for a daily maximum noise exposure equivalent to 90dB (A) over 8 hours. This is the measure taken to protect against the damaging effect of noise.[87,88] This in addition, recommends the use of hearing protection once the sound levels are above 85dB (A). Noise intensity above 90dB is injurious to the hearing apparatus. However, if the exposure time is reduced as the intensity increases, the total

energy equivalent on the ear remains within safe limits .[88] Table 2.1 below shows the different sound intensities against the safe exposure time duration.

Table 2.1: Permissible noise level exposure

Duration per day (hours)	Intensity (dBA)
8	90
6	92
4	95
3	97
2	100
1.50	102
1	105
0.50	110
0.25 or less	115

Source: Ajuyetsi and Bolaji,2003

Among workers in Taiwanese stone factories, measurement of environmental and personal noise levels demonstrated that more than 50% of workers were exposed to noise levels above 85dB(A) with a number being greater than 90dB(A). In addition, in seven out of nine cases, personal noise level measurements were greater than the environmental measurements by an average of 5.3dBA.[89] The cotton ginning industry in India is known to employ a significant number of people who unfortunately are exposed to excessive levels of noise. This was established when estimates of the environmental noise they were exposed to over 12hr work shifts was assessed to range between 89 and 106dB(A).[9]

In Ghana, environmental noise measurements recorded in a stone crashing company in the formal sector noted maximum sound levels at various workstations ranging between 91.8dB(A) to 99.6dB(A), way out of range of the permissible noise levels by law.[5] Further, in the informal sector where regulations are not enforced, in the same country, corn mills in market places in two different cities assessed for noise levels showed levels ranging between 85.9dB(A) minimum to as high as 110.8dB(A).[17,19]To cap it all, still within the country, workers across various industries – sawmills, surface gold mining, quarries, and printing presses- have been demonstrated to be exposed to noise intensities far beyond permissible limits as high as 120dB (A) in investigations done across different locations in Ghana over the past decade and a little beyond .[18,19,21]

The military is another occupational setting where personnel are exposed to high intensity noise with consequent auditory effect as well as other health implications. Activities that lead to noise exposure among military men include noise from firearms e.g, hand gun shooting, radio communicators and vehicle sirens.[90] A case control study carried out among 115 military personnel in Brazil of which 65 were regularly noise -exposed through practicing of handgun shooting showed that 25% had NHIL as against 0 among controls with PTA. However, when TOAE was used in the assessment, 58.92% (33) were found to have absent readings bilaterally. Sound level of the firearm measured close to the ears of participants ranged between 119dB-133dB(C). About 50 shots were fired within 2-4 hours giving a series of 10 shots at about 2 minutes interval.[91]

Musicians form another occupational group with a considerable amount of noise exposure through rehearsals both personally and with their groups as well as during performances. 63 Helsinki musicians from four classical orchestra groups were studied for noise exposure and consequent NIHL. They were found to be exposed to an average of 90dBA of noise during rehearsal sections which is above the stipulated national action level of 85dBA at which noise induced injury to the ear is present. This group however was not found to have a hearing loss prevalence higher than the general population although those with higher noise exposure were typically found to have the hearing impairment in the higher frequencies from 3kHz and above.[92] When compared to subjects in industry, these orchestra staff appeared to have a lower prevalence for age than their peers in the industrial setting.

Other studies among other musician groups have however found higher prevalence of hearing loss among them though with different incidences.[93,94] Whilst the study of German orchestra musicians by Emmerich found 50% of the subjects to have Permanent Threshold Shift (PTS) of 15dBA, Laitenen and Poulsen stated a 25% incidence of self-reported hearing loss among Danish orchestra musicians. Despite all the above, the interesting phenomenon of ‘protective mechanism of sound conditioning’ has been demonstrated whereby prolonged exposure to low intensity music has been found to infer some protection against the deleterious effects of noise trauma.[95,96] However, though subjects were noted to have an improved hearing acuity and musical perception after musical training when conventional audiometry was used, extended high frequency audiometry in the range of 12, 14 and16kHz showed a decreased average acuity at these frequencies indicative of noise induced trauma .[97]

A systematic review of literature by Zhao et al[98] concluded that exposure to loud music – either in the professional setting or as a recreational activity - occurs among many individuals. They noted that levels of exposure often times exceed the levels that are even allowed in industrial settings. Assessments of these individuals lead to findings of Temporary Threshold Shift, tinnitus and hyperacusis which are indicative of noise induced injury to the ear.[98]

The construction industry is another occupation with high noise exposure levels exposing workers to NHIL. A review and analysis by Suter of construction workers found most being exposed to noise levels above 85dBA. Those with the highest exposure were highway and street construction, carpentry and concrete work. Specifically, ironworkers and boilermakers were found to be most exposed at 105dBA and 108dBA respectively. [99] A study of 40 Spanish construction workers revealed 50% being exposed to noise levels exceeding 87dBA with those who worked with machines having exposure levels of over 90dBA. [100]

2.5 Effect of Noise on Health

According to the WHO, an adverse effect of noise is defined as a temporary or long-term change in the morphology and physiology of an organism that results in impairment of functional capacity, or an impairment of the capacity to compensate for additional stress, or increases the susceptibility of an organism to the harmful effects of other environmental influences.[101] Though most people recognize hearing loss as an obvious effect of noise, with associated tinnitus, loudness recruitment and paracusis, other effects like sleep disturbance, migraine headaches, cardiovascular diseases, anger and irritability as well as interference with learning in children are among the other recognized health effects of noise.[6,7,74,102]

Among a group of soldiers exposed to noise from firearms studied in Brazil, a majority (78%) were aware of noise and its effects on health and were of the opinion that they could acquire hearing impairment from the noise exposure.[91] Though not to the same extent, they were also aware noise could cause ear ache (6.15%), stress (15.35%) and headache (6.15%). For them personally, they experienced tinnitus (23%), temporary hearing loss (7.6%) headache (3%) and irritability (3%) after shooting practice.[91]

Musicians in four orchestra companies who were investigated for NIHL and other noise associated health concerns reported of having had tinnitus sometimes, often or always (40%) and hyperacusis (84%) after noise exposure during group or personal rehearsals or performances .[92]

Maron et al[103] in their study of PLD use in a group of college students concluded that majority were aware of the harmful effects high intensity music could have on their hearing. Of these, 125 out of 171 believed that exposure to loud music for 1-2hrs could adversely affect their hearing[103]. Nigerian mill workers investigated for occupational NIHL were found to complain of hearing problems (24%) with tinnitus being the most common complaint. [16]

Among U.S. workers, Masterson et al found a prevalence of hearing loss, tinnitus or both to be 23%, 15% and 9% respectively among noise exposed workers whereas their non-exposed counterparts had prevalence of 7%, 5% and two percent respectively for the same conditions pointing to the exposure on noise effect on the ear. [104] Workers in a Brazilian textile industry with industrial noise exposure were studied and found to have complaints of hearing loss (30.8%), tinnitus (9.6%), aural fullness (5.8%), otalgia (3.8%), difficulty in understanding speech (25.0%) and dizziness (3.8%) [41].

A group of petrochemical industry workers in Iran followed to assess for development of NIHL and hypertension after noise exposure were later found to have a prevalence of hearing loss of 38.5% as against 7.8% among controls. Auditory symptoms of vertigo, tinnitus, disturbances of speech perception and voice recognition were more prevalent among the exposed group as well as symptoms of sleep disturbance. In addition, whereas the unexposed group had a prevalence of hypertension 0f 12.8%, the exposed group was ahead at 20%.[105]

2.6 Hearing Protective Devices and Their Use

The need to preserve hearing and avoid the other physiological effects of noise exposure in the industry cannot be overemphasized. This is important both for the employer who can save tremendously on compensations paid once the hearing loss is established and more importantly, the employee who will pay the price of hampered verbal communication and its effects on social life as well as all the other associated debilitations due to excessive occupational noise exposure.

Regulatory bodies of occupational health and safety organizations have in place hearing conservation programs (HCPs) aimed at reducing the disabling hearing loss from work place noise. HCP refers to an organized activity aimed at prevention of NIHL, typically including noise measurements, routine audiometry, noise reduction and education of workers primarily in the use of hearing protection devices.[106] It consists of a hierarchy of measures whose implementation goes to achieve their purpose:

- Elimination
- Substituition
- Engineering Controls
- Administrative Controls
- Personal Protective Equipment (PPE) Use

These measures as arranged are in the order of most effective to least effective from top down.[107] Whilst elimination consists of completely removing the hazardous agent, substitution allows for the replacement of the hazard with other entities that could perform its function. Engineering controls seek to address equipment management and processes of doing things that will generate less of the hazard. Administrative controls serve to change the way or the environment in which people work. Finally, the use of PPEs is the last line of defence to mitigate NIHL in the industry.[108]

Commonly used PPEs against noise exposure are the Hearing Protection Devices (HPD). These are equipment worn in or over the ears to help prevent NHIL whilst exposed to hazardous noise. Though they do not eliminate the noise entirely, they reduce the level of noise entering the ear. Different types of HPDs are available and they include:

- Earmuffs – two ear cups that fit over the pinna joined by a head band
- Earplugs – these fit in the ear canal
- Electronic hearing protection devices – combine structural and electric components to cause sound level attenuation or noise cancelling. Available in earmuff or earplug

forms, some of these devices allow transmission of other sound like speech whilst reducing harmful sound.

- Semi-inset devices /canal caps
- Dual Hearing Protection – simultaneous use of earmuffs over earplugs, recommended in the mining industry.

Figure 2.10: Hearing protective device - an ear muff

Source:www.iosh.co.uk/Books-and-resources/Our-OH-toolkit/noise.aspx

Ear-muffs are hard plastic cups that fit over and surround the individual's ears and are sealed to the head by cushion seals. These are usually manufactured from plastic materials with a metal or plastic head band and foam or liquid ear cushion. Depending on the material used, the ear-muffs can irritate skin around the ears, particularly in warm weather. Advantages of using ear muffs include:

- more protection at higher frequencies than ear-plugs
- designed to fit most people
- less time and effort required to apply
- easy to supervise and monitor from a distance
- not easily misplaced or lost because of large size
- various noise reduction ratings available
- can be worn with minor ear infections
- re-useable, durable and longer lasting than ear-plugs.

Their use is associated with some disadvantages and these include:

- rather less portable and relatively heavier than ear-plugs
- requires adequate storage facilities
- can be uncomfortable in hot and humid environments
- rather expensive to buy or to replace
- can be inconvenient to use with other personal protective equipment.

Ear-plugs come in wide variety of forms, mostly manufactured from soft plastic, PVC, silicone and polyurethane. They provide good sound attenuation when fitted correctly. The type of ear-plug chosen will depend on each individual's needs and personal preference. Advantages associated with the use of these devices include:

- small and easily carried
- easy to use and store
- more protection at lower frequencies than ear-muffs
- various noise reduction ratings available
- inexpensive, therefore cheap to buy and replace

- can be custom-molded for individual workers
- convenient to use with other personal protective equipment such as safety glasses
- comfortable to wear for longer periods, especially in hot and humid work environments.

They also come with some disadvantages and these include:

- improper insertion reduces noise reduction rating value
- can be difficult to insert and remove (e.g., for individuals with small ear canals)
- requires good personal hygiene practice (can introduce dirt into ear canal)
- may irritate the ear canal
- more difficult to monitor usage.

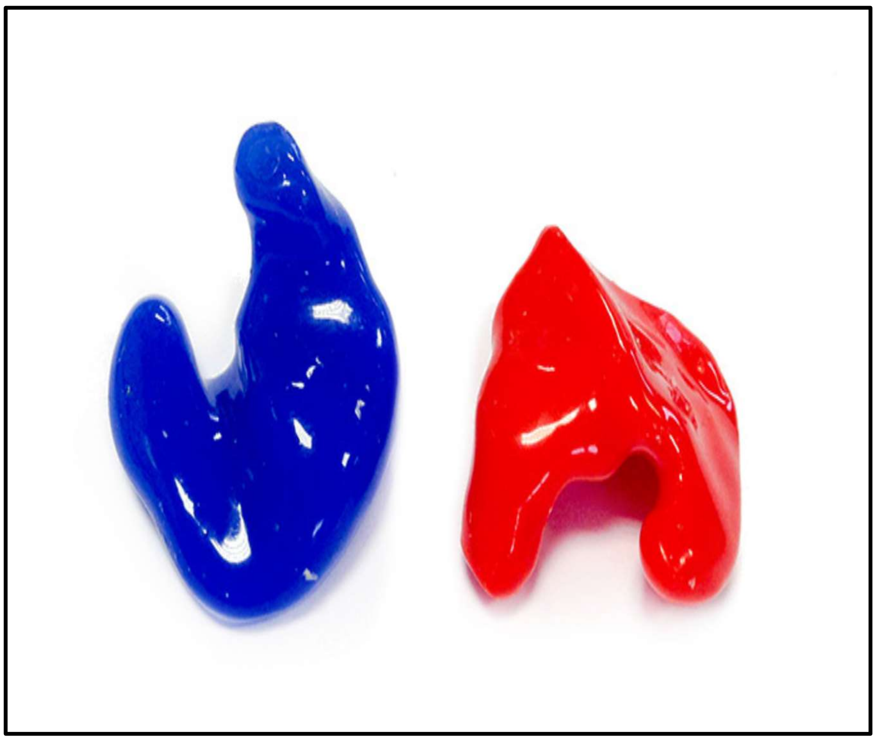


Figure 2.11: Hearing protective device - ear plugs (custom moulded)

Source:www.iosh.co.uk/Books-and-resources/Our-OH-toolkit/noise.aspx

Figure 2.12: Hearing protective device – regular ear plugs

Source:www.iosh.co.uk/Books-and-resources/Our-OH-toolkit/noise.aspx

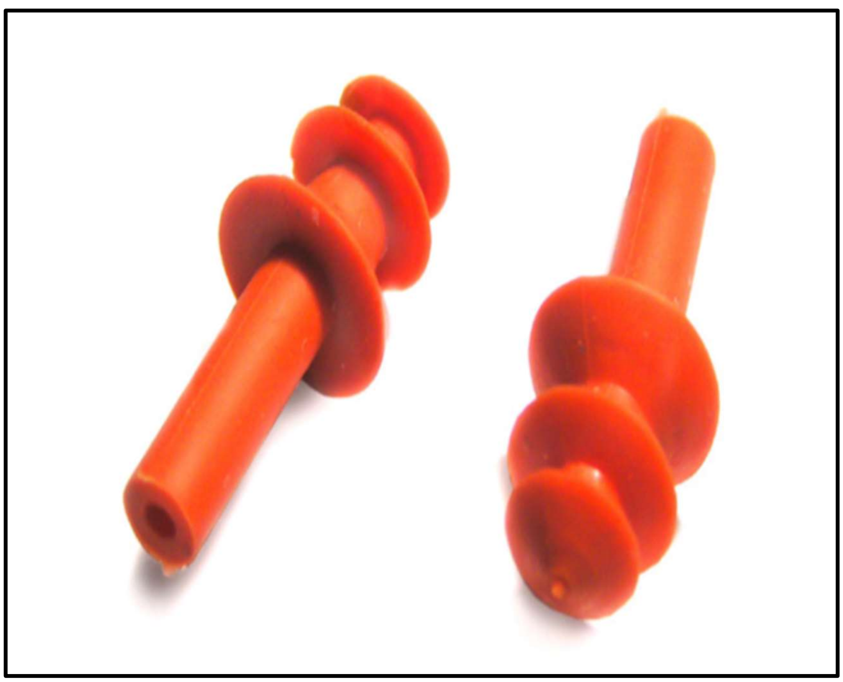


Figure 2.13: Hearing protective devices - specialist ear plugs for certain occupations

Source: www.iosh.co.uk/Books-and-resources/Our-OH-toolkit/noise.aspx

Canal caps have rounded heads that cover the entrance to the ear canal, while semi-insert plugs generally have conical tips that are pushed into the ear canal. Both types are convenient for situations where the hearing protection has to be taken on and off frequently. Firm pressure from the head band is required to maintain an effective seal, which can be uncomfortable over longer use. These are normally recommended for use in areas of intermittent noise. The reason they will be preferred include:

- various noise reduction ratings available
- easy to insert
- may be used several times
- ideal for people going in and out of noisy areas.

Disadvantages to their use are:

- correct size may be required
- improper insertion reduces effectiveness
- more expensive than ear plugs
- typically have lower noise reduction ratings than plugs or muffs.

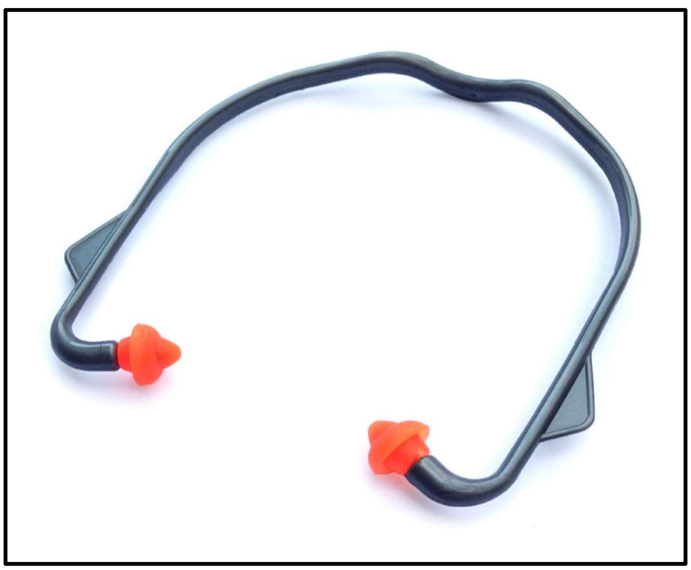


Figure 2.14: Hearing protective devices - semi-insert device

Source: www.iosh.co.uk/Books-and-resources/Our-OH-toolkit/noise.aspx

In the U.S, NIOSH recommends the use of HPDs once there is exposure of an 85dBA or more during an 8-hour work day. Whenever it is difficult to control the environmental noise, or the person cannot be removed from the environment, then it becomes imperative to use these devices. The more accurate the fit or insertion of the device, the better the sound attenuation provided.[107,108]. Factors that affect the effectiveness of HPD use include:

- Barriers to adequate use
- Comfort related issues
- Convenience
- Lack of training
- Beliefs and attitudes towards its use [109,110]

The effectiveness of a well fitted HPD is measured by its noise reduction rating (NRR) which is an estimate of how much noise is reduced by the use of that device in decibels. In the US, NIOSH recommends test fitting of the device by an individual to determine the actual noise level attenuation offered by the device to the individual.[111]Among a group of Thai workers with hazardous noise exposure, Tantranont et al found a 77.9% use of hearing protection devices with workers who perceived themselves to have good hearing more likely to use the HPD. In this study, participants were also found to be more likely to use the devices if their colleagues and supervisors used theirs.[109]

In an investigation in two South African mines, almost all subjects were aware of the importance of the use of hearing protection devices, with only 50% reporting consistent use of these devices.[10] Again, within the South Africa mining industry, another study demonstrated that 89% of workers believed HPDs were beneficial. These workers were aware that they worked in a noisy environment (84%) and that this was detrimental to their hearing (82%). Within this cohort only 24% used their HPDs at all times. Though 93% of these workers reported that they used their HPDs, only 50% were actually observed doing so. Use of HPD was found to be higher with higher skill level.[112]. Reasons for not using HPDs included discomfort (50%), interference with hearing warning signals (23%), HPDs not working (13%) or falling out of the ears (10%).[112]

Within the West African sub-region, a steel rolling mill in Nigeria found only 27% of workers having HPDs and even of these, only 28% used them. This was the case despite the fact that among these same workers 93% were aware of the hazards of noise almost all of these people were aware of methods to prevent effects of this hazard.[113] An experimental research conducted among oil depot workers found that the group of workers who used HPDs were noted to have an improvement in hearing threshold whereas the cohort who were similarly exposed to sound levels of 130dB were found to have normal hearing levels decreased from 52% to 32% after six months of exposure.[113]

When Kitcher et al investigated Ghanaian market mill workers with regards to occupational noise induced hearing loss, only 5% were found to use HPDs despite 54.5 % of them being aware of the effects of noise on health.[17] A study by the same author among workers in a stone crashing company grouped as being part of the formal sector surprisingly found almost the same proportion of workers who use HPDs (5%) in Ghana. This is despite the fact that 87.5% had sound knowledge in the effects of noise on hearing.[5] There was no indication however for the low level of hearing protection device usage despite the high knowledge of the effects of noise on hearing and health.

In the study by Win et al of police officers in Brunei Darussalam, of whom 34.2 % were found to have NHIL, 37.9% and 36.4% of the males and females respectively did not use the provided ear muffs during shooting practice though they are mandated to do so.[81] Of the Brazilian group of military personnel studied by Heupa et al[91], 92.3% of those exposed to firearm noise used hearing protection devices. Though they had been provided with ear muffs, they had the choice of acquiring and using any other type of HPD they wanted and this was demonstrated by the fact that 70.7 % rather used the insert -type devices.[91] Kuwaiti air force pilots studied for NIHL found that though all the pilots used hearing protection whilst flying, the fighter pilots used helmets, ear muff and Active Noise Reduction whereas the helicopter fliers used only the ear muffs and helmets as noise attenuation devices.[80]

When enquired about their use of HPDs, a group of musicians in Finnish National Opera mentioned that they were driven by the fear of losing their hearing and of having tinnitus to use the devices. They also used them to avoid pain in the ears, stress, irritability and fatigue. Other reasons were to prevent worsening of an already present hearing loss and tinnitus. Reasons that deterred them from using the devices were fear of poorer performance when using them and the fact that the presence of hearing loss made it more difficult to use the HPDs.[94]

In Ibadan, Nigeria, a study of 85 mill workers exposed to noise levels between 88-105dB found that none used hearing protection devices despite the high level of noise.[16] Consequently, there was a significant percentage (56%) having hearing impairment identifiable to be noise induced.

In a similar situation, 55 Taiwanese stoneworkers exposed to detrimental noise were observed by Huang et al to use no hearing protection despite regulations by the Taiwan Occupational and Safety Regulatory Act. This group were also determined to have greater than 70% hearing threshold above 25dB among participants.[89]A study among a group of college students on the use of personal listening devices showed usage of hearing protection devices in 8% of them when there was the need to do so.[103]

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Design

A comparative cross-sectional study was conducted in the city of Accra and its suburbs, comparing workers in block factories who were noise exposed as subjects and controls with no occupational noise exposure.

3.2 Study Population

The study population consisted of 143 adult (142 males and 1 female) cement block factory workers ranging between the ages of 18-50years (the arbitrary age at which age-related hearing loss sets in).[114] All workers on site who consented were included. They consisted of both operators of the machines and labourers as well as those in administrative roles when such distinctions were present. The controls were 132 members of staff within Korle-Bu Teaching Hospital made up of 94 males and 37 females matched for age.

3.3 Study Site

Cement block factories located in the Weija-Gbawe municipality of the Greater Accra Region of Ghana were the study sites. The Weija- Gbawe municipality was randomly selected among a group of five municipalities with rapid and active infrastructural development in the region. The random selection was carried out by writing out the five municipalities and blindly picking one out. Being a developing area, one of the five municipalities with active springing up of mainly residential and also business infrastructure with the others being Ga West (capital – Amasaman), Ga East (capital - Abokobi), Ga South and Ga Central (capital – Ablekuma) with numerous residential and business facilities springing up, the municipality has several small-scale cement block factories actively operational in the manufacture of blocks. Twenty-three of the factories are formally registered with the municipality with about slightly higher number not officially known to the municipal directorate. Thirty block factories within the municipality were randomly selected. Workers within the factories were then engaged to participate in the research. In all, a total of nineteen (19) block factories were involved in the study. These were of two categories: the "traditional" factories and the "modern" high output factories.

The traditional factories, which were the majority, usually employed an average of 6 workers with one operator who run the machine to mould the blocks and the others who were engaged in mixing, loading and packing the blocks once they were moulded. These factories used small sized China-made machines that moulded single blocks at a time or Ghanaian made machines (Appendix 8) that moulded two cement blocks at a time.

Each machine run a cycle of loading, moulding and offloading which run in cycles of about 40 seconds each, with the machine running and moulding (at which point the maximum noise level is attained) lasting an average of 17 seconds. This cycle runs through the day until all available pallets have been filled or a rainy weather interrupts work. There are supervisors or managers who may be involved in the production itself or watch from an office within the vicinity of the factory. In these factories all workers with the exception of the supervisors who are not involved in the moulding process are exposed to the same level of noise.

The high output "modern" factories on the other hand employ an average of 25 workers each in various aspects of the production process with few exposed to the hazardous noise from the machines. These machines churn out between 8 to 12 units of cement blocks at a time reaching production levels of 8,000 to 12,000 units of cement blocks in a day. The workers are in groups of material carting, machine operating, loading and packing of dried out blocks. There are drivers who transport sold blocks as well as mechanics who maintain the machines.

The machines in these factories (Appendix 9) run in cycles lasting about 60 seconds with maximum noise levels lasting briefly over 5 seconds. In these factories only the machine operators are exposed to the hazardous noise constantly. The rest of the workers are exposed in brief periods throughout the working hours as they shuttle between the moulding and the packing sections of the factory.

The work at the block factories entails making of cement blocks of varying thickness and compactness. They are made from a mixture of sand, cement and water with others having additional stone chippings. These components are delivered to the site by trucks and manually mixed or mixed with concrete mixing machines. Mixtures are then compressed with the block making machines –

the major source of high frequency noise. These machines are loaded with the mixtures either manually (traditional) or mechanically and compressed. The formed products are carried off to sun dry and the procedure is repeated in about two minutes time. Workers are usually close to the machines either filling, awaiting compression by the machine or carting off the formed blocks.

Work begins at about 8 o'clock in the morning and closes at 5pm with an hour break which is staggered among workers. Work is usually for six days in a week with a break on Sundays. Workers are allowed days off as and when required. On some days, work does not go on because of rainy weather or when the yard is full of blocks that have not yet been bought.

Workers are mainly casual workers, earning their wages by the day, depending on how many cement bags are used or how many blocks are produced in the day. They are under no obligation to report on a daily basis. Those who tend to be permanent workers are the machine operators whose occupation is machine operation. The rest mostly come in and go depending on when they need a quick source of income.

With the machine running for one minute every three minutes, in a day of active work, there is intermittent high frequency noise exposure of about 3 hours cumulatively in one day with one machine running. Where there are two machines working concurrently the noise is persistent the whole day.

Study participants who were controls were staff of the Korle Bu Teaching Hospital in the Ablekuma South sub-district of the Accra Metropolis. KBTH is a tertiary institution with a 2000 bed capacity and over 1500 daily out-patient department (OPD) attendance. Established in 1923 with the purpose of addressing the health needs of the indigenous people, it has now expanded with numerous areas of specialty and centres of excellence. It is the largest referral facility in the West African sub-region serving individual from many countries in the location. In partnership with the University of Ghana, it is a training institution for medical practitioners as well as other allied healthcare professionals.[115]

The hospital has a staff strength of over 4,969 individuals made up of clinical staff and non-clinical staff at a ratio of 5:3.[115] Members of the clinical staff include doctors, nurses and midwives, pharmacists, dieticians, audiologists and medical laboratory technologists and technicians among others. Non clinical staff include administrators, account officers, procurement officers, information technology professionals, security personnel, canteen attendants, engineering staff among others. All these personnel are graded according to various levels of their career stages. They are also grouped under various sub-BMCs, the units under which the hospital runs on a day to day basis.[115]

On the hospital premises is the Hearing Assessment Centre where the audiometric evaluation of subjects was carried out. Equipped with an audiology booth which is sound treated, the ambient noise level is averaged at 37dBA within the booth. Outside the booth but within the rest of the rooms and offices of the facility which are quiet, the ambient sound level is averaged at 48dBA.

3.4 Inclusion and Exclusion Criteria

3.4.1 Inclusion Criteria:

- Age 18 - 50 years
- Worked at the factory not less than one month
- Willingness to participate in the study

3.4.2 Exclusion Criteria

All workers with:

- Already existing hearing loss of other identifiable causes other than NIHL
- Findings of external auditory canal or middle ear pathologies detected on pre-screening otoscopy and tympanometry such as impacted wax, otitis externa, perforated tympanic membranes and middle ear effusion.
- Age above fifty (to avoid age related hearing loss).
- Previous head trauma and use of ototoxic drugs.

3.5 Sampling

3.5.1 Sampling Procedure

The total number of factories within the municipality was 56. A total of 30 factories were selected by systematic random sampling. The sampling interval for the number of factories was given by

50/30 = 1.67, rounded up to 2. The starting point was selected by tossing of a coin from the first two on the list. After the starting point this was followed by every other factory on the list. When the list was exhausted the process was continued till all the 30 factories were selected. All eligible and consenting workers in the selected factories were recruited into the study.

All workers in all selected factories were recruited once they consented (Apendix 1 and 2) to join in the study. Again, for the controls, all staff of KBTH who consented to take part in the study who were matched to the age and sex were possible were recruited with the main criteria being their non-exposure to excessive occupational noise.

3.5.2 Sample Size Determination

The minimum sample size was 293 calculated at a 95% confidence level and a statistical power of 80% with a 10% attrition rate considered using the formula:

$N = 2. [Z_{Crit} \sqrt{\ 2\bar{p}\ (1-\bar{p})} + z_{pwr} \sqrt{\ p_1\ (1-p_1) + p_2\ (1-p_2)}]^2 / D^2$.[116]

Where:

P_1 – estimated population of block factory workers =0.248

P_2 – estimated population of controls = 0.048

$\bar{p}$ - $p_1 + p_2 /2 = 0.148$

$D – p_1 – p_2 = 0.2$

Z_{crit} – 1.96 (at 95% confidence level)

Z_{pwr} – 0.842 (statistical power)

Therefore

$N = 2. [1.96 \sqrt{\ 2(0.148)\ (1-0.148)} + 0.842 \sqrt{\ 0.248\ (1-0.248) + 0.048\ (1-0.048)}]^2 / 0.2^2$

N = 266.4

N ≈ 266

At 10% attrition rate,

Sample size was calculated to be 292.6

≈ 293

After cleaning of incomplete data, a total of 275 participants were included in the analysis, consisting of 143 cases and 132 controls.

3.6 Data Collection Procedure

Data was collected over a ten-month period (March 2021 to December 2021) using a semi-structured questionnaire on sociodemographic characteristics, knowledge on effects of excessive noise exposure on hearing and awareness of the availability of hearing protection devices and their use. The questionnaire also assessed their duration of service at the factory and work description (Appendix 1).

Level of noise in the various cement block factories was measured using the sound level meter with A-weighting when the machines were in full operation and when they are paused at different locations in the factory. The sound level meter used was the Larson Davis model 825 Type 1 sound level meter with serial number 824A0483 manufactured by PCB Piezotronics Incorporated, USA. Answering of questionnaires and testing of subjects were all done over the study period.

Workers had otoscopic examination using a portable Piccolight pocket otoscope, followed by tympanometry to rule out any outer and middle ear pathologies which excluded them from the study. However, those who agreed were treated and participated where possible. For instance, workers found to have impacted wax or debris, otomycosis or otitis externa were treated and included: wax was oiled and syringed after a week, otomycosis was treated with antifungal ear drops after syringing if there is no ear pain associated (candibiotic ear drops) and otitis externa with topical antibiotic ear drops.

Audiometric measurements to ascertain the hearing threshold of the workers was done by pure tone audiometry - both conventional and Extended High Frequency (EHF) using the Interacoustics AC40 Clinical Audiometer manufactured in Middelfort, Denmark. In the determination of the hearing threshold at the various frequencies, the subjects were positioned in the sound treated room with an ambient noise level of 34 to 40dBA where instructions were given as to how the procedure would be undertaken.

The better hearing ear (if any) was assessed first. They were provided with the ear phones through which the tones were presented (between 1-3 seconds) and they were to respond to tones heard no matter how faint. A familiarization tone was presented at greater than or equal to 30dB and if not heard, increased in steps of 20dB till subject perceived the sound whilst observing his demeanour and manner of response. The frequencies were tested in the order: 1, 2 (3), 4, (6), 8, 0.5, 0.25 then 1 kHz again.

For the purpose of assessing the threshold at the extended high frequency range, the audiometry was continued at 11.2, 12.5, 14 and 16kHz. For the second ear, there was no repetition of test at 1kHz. At each frequency a tone above the threshold was started with and reduced in 10dB steps till no longer heard. The tone intensity was then increased in 5dB steps till perceived again. This procedure was repeated till the intensity where the tone could be perceived at least 50% of the time when ascending and this was recorded as the threshold for that particular frequency. This is the Hughson-Westlake method of threshold assessment.[29]The Pure Tone Average ($PTA_{.5124}$) was calculated using the threshold at 0.5, 1,2 and 4kHz, and also at 2, 3 and 4 kHz since the 0.5 and 1kHz are resistant to NIHL.[17] The high frequency PTA was also calculated at 3, 4 and 6kHz[1,17] and threshold characteristics of the extended high frequencies were described.

This was followed by DPOAE measurements. DPOAE was measured with the Sentiero Diagnostic model SOD10097 with serial number 550773 manufactured by Path Medical GmbH, Germany using the DPOAE probe. To allow better placement and manipulation in the ear canal, an acoustic immittance probe tip was inserted over the DPOAE probe. The size of the probe tip was matched to the size of the ear canal. Individual in-the-ear calibration was used. The patient was instructed to be calm and still and the cables of the earphones was long to allow it to hang loosely and not rub on clothing.

The DPOAE measurements were done in a quiet room in the hearing assessment centre. The delivery of the acoustic stimuli to the ear canal conformed to the International Electrotechnical Commission audiometric equipment requirements (IEC 60645).5 Distortion product grams (DP grams) were plotted with the following parameters for the two-primary stimulating tones f1 and f2: f2/f1=1.22. The stimuli levels were kept constant at L1=65 dB SPL and L2 = 55 dB SPL. Stimulus frequency f1 used were 2, 3,4, 6, and 8kHz. To ensure measurement validity, the residual noise floor was set to be at least 6 dB below the 2f1–f2 distortion product signal.[63] Abnormal result of DPOAE was considered at lower than 10dB response amplitude.[117]

All hearing threshold assessments were carried out at least 18 hours from last exposure to noise to avoid measurements of temporary threshold shifts. Workers were assessed in batches of fifteen or less per day. This was carried out in the Hearing Assessment Centre in Korle Bu Teaching Hospital which is well equipped with a sound-proof booth with a desired ambient noise level. Subjects were transported from their factories by vans hired by the principal investigator for such a purpose to the centre. Participants were given the choice of waiting till the end of the day for all other participants to complete the test before being sent back to their various facilities or of going home by themselves by public transport with transportation fare provided by the primary investigator. Those who waited were provided with lunch and/or snacks

3.7 Pre-testing of questionnaire

Pre-testing of questionnaire was done using a group of workers in a cement block factory with similar demographic and occupational features. This was done to ensure clarity, check for logic in the sequence of questioning and determine the average time used in answering the questionnaire and performing the various hearing assessment tests on participants.

3.8 Data Management and Analysis

3.8.1 Data management plan

Unique codes were assigned to each participant during the study to enhance easy tracking, sorting and for confidentiality. Information sought was kept in a locked cabinet. Additionally, soft copies of data generated relating to the research were saved electronically and this was password protected. Only researcher had preview to participant's information;

3.8.2 Statistical analysis

Data was captured and cleaned in Microsoft Excel and analysed using Statistical Package for Social Sciences (SPSS) version 23. Shapiro–Wilk test was used to test for normality of data. Demographic variables were presented as descriptive summary. Continuous variables with normal distribution were summarized as means and /standard deviations, while skewed variables were summarized as median and interquartile ranges. Categorical variables were summarized as frequencies and proportions. Summaries were presented in tables and charts or figures where appropriate. Comparisons of the pure tone averages between the noise exposed and the nonexposed groups was done by independent t-tests.

The mean threshold level of hearing for both subjects and controls were calculated using thresholds at 500Hz, 1kHz, 2kHz and 4kHz (PTA_1): and again, at 3kHz, 4kHz and 6kHz (PTA_2). The threshold for the EHF was also noted at each EHF and compared with PTA_1 and PTA_2. The pure tone average value of 26dBA and above as well as all EHF thresholds greater than 25dBA were categorized as hearing loss.

Comparisons of percentages of individuals with hearing loss between the noise exposed and non-exposed was done using chi-square tests. Similarly, the prevalence of hearing loss obtained using the different assessment tools (conventional PTA, EHFPTA and DPOAEs) were compared using the chi-square test. An audiometric notch at 4000Hz was identified and compared between the exposed group and controls. A 4kHz notch was defined when the 4 kHz threshold minus the 3kHz threshold was ≥10 and the 4 kHz threshold minus the 6kHz threshold was ≥5 dBA. All statistical tests were considered significant at alpha level = 0.05 or $p<0.05$.

3.9 Ethical Consideration

Ethical approval was obtained from the Scientific and Technical Committee/Ethical Review Board of Korle Bu Teaching Hospital (KBTH- /IRB/000177/2021, Appendix 4). Approval was also given by the Ghana College of Physicians and Surgeons before the commencement of the study. Permission was sought from the managers of all block factories included in the study. Informed consent was obtained from all the participants before they were recruited into the study. The entire process was explained to the participants in a language of their choice. They were encouraged to ask questions. Participants were allowed to withdraw from the study at any time if they so wished. All participants were assigned unique ID numbers to protect their identity. All information collected was treated with strict confidentiality. All individuals found to have NIHL or any other pathology detected in the process of data collection were counselled appropriately.

Data collection sheets were stored under lock and key and soft copies were password protected and assessable to only the principal investigator. Results obtained from the study was used for research purposes only. No specific individual benefit was promised to any participant. Any complication that arose out of the study was managed at a cost to the research team.

CHAPTER FOUR

4.0 RESULTS

4.1 Overview of Data

In this study, a total of 288 subjects were recruited with 13 excluded on account of middle ear effusion (2), incomplete data (5) and impacted wax (6). In all, a total of 275 subjects with 550 ears were examined. Subjects consisted of two groups: 143 cement block factory workers with exposure to industrial noise from the factories and 132 controls who had no occupational noise exposure. Whereas almost all (142) the cement block factory workers were males, the control group consisted of 94 males and 37 females.

The cement block factory occupational groups included machine operators (22.4%), labourers (72.1%) and others (3.5%). Controls were either clinical staff (60.6%) or non- clinical staff (39.4).

4.2 Demographic characteristics of block factory workers and controls

The demographic characteristics of the block factory workers and controls are presented in Table 4.1 below.

The mean age of the cases was 29.3 years ±9.2 years and a median age of 26 years compared to that of the controls was 28.6years ± 6.7 years and a median age of 26.5 years. For the cases, the age range was 18 - 50 years whereas the age range for the controls was 20 – 49 years (Figure 3. 1). There was no significant difference between the ages of the cases and the controls ($p > 0.724$)

The majority of block factory workers (67.8%) had their highest level of education being the secondary school level (both junior high school (54.6%) and senior high school (45.4%) or equivalent). Of the controls, 84% were of the tertiary level of education.

The mean duration of service for the block factory workers was 3.0 ± 3.2 years, ranging between 0.2 – 24 years. Their mean hours of work per day was 8.1 hours with a standard deviation of 0.6 hours. Averagely, the block factory workers worked for 51.6 hours ± 6.4 hours a week resting 1 day a week.

The mean duration of service for the controls was 4.4 years ± 3.57. The minimum duration was 0.2 years, and the maximum was 22 years. Their mean hours of work per day was 8.0 hours with a standard deviation of 0.9 hours. The mean number of hours they worked in a week was 42.5 hours ± 7.2 hours. Their days of rest within a week averaged 1.8 days ± 0.4.

Table 4.1: Demographic characteristics of study participants

Variable		Frequency (%)		p-value
		Case (*n* = 143)	Control (*n* = 132)	
Age (years)	up to 20	20(14.0)	-	
	21 - 30	81(56.7)	91(68.9)	
	31 - 40	23(16.1)	32(24.2)	
	41 – 50	19(13.3)	9(6.8)	
	Mean	**29.3 ± 9.2**	**28.6 ± 3.7**	**0.724**
Educational level	None	2(1.4)	-	
	Primary	40(28.0)	-	
	Secondary	97(67.8)	13(9.8)	
	Tertiary	4(2.8)	119(90.2)	
Occupation	Machine Operator	32 (22.4)	-	
	Laborer	106 (74.1)	-	
	Others	5(3.5)	-	
	Clinical Staff	-	80(60.6)	
	Non-Clinical Staff	-	52(39.4)	
Chronic disease	Yes	-	1(0.8)	
	No	143(100)	131(99.2)	
Duration of work (years)	< 1	14 (9.8)	8(6.1)	
	1 - 5	115(80.4)	96(72.7)	
	6 - 10	10 (7.0)	21(15.)	
	11 - 15	2 (1.4)	5(3.8)	
	> 15	2 (1.4)	2 (1.6)	
	Mean	**3.0 ± 3.2**	**4.4 ± 3.57**	
Hours of work/week	≤ 40	-	98	
	> 40	143(100)	34	
	Mean	**51.6 ± 6.4**	**42.5 ± 7.2**	
Days of rest / week	1	143(100)	31	
	2	-	101	

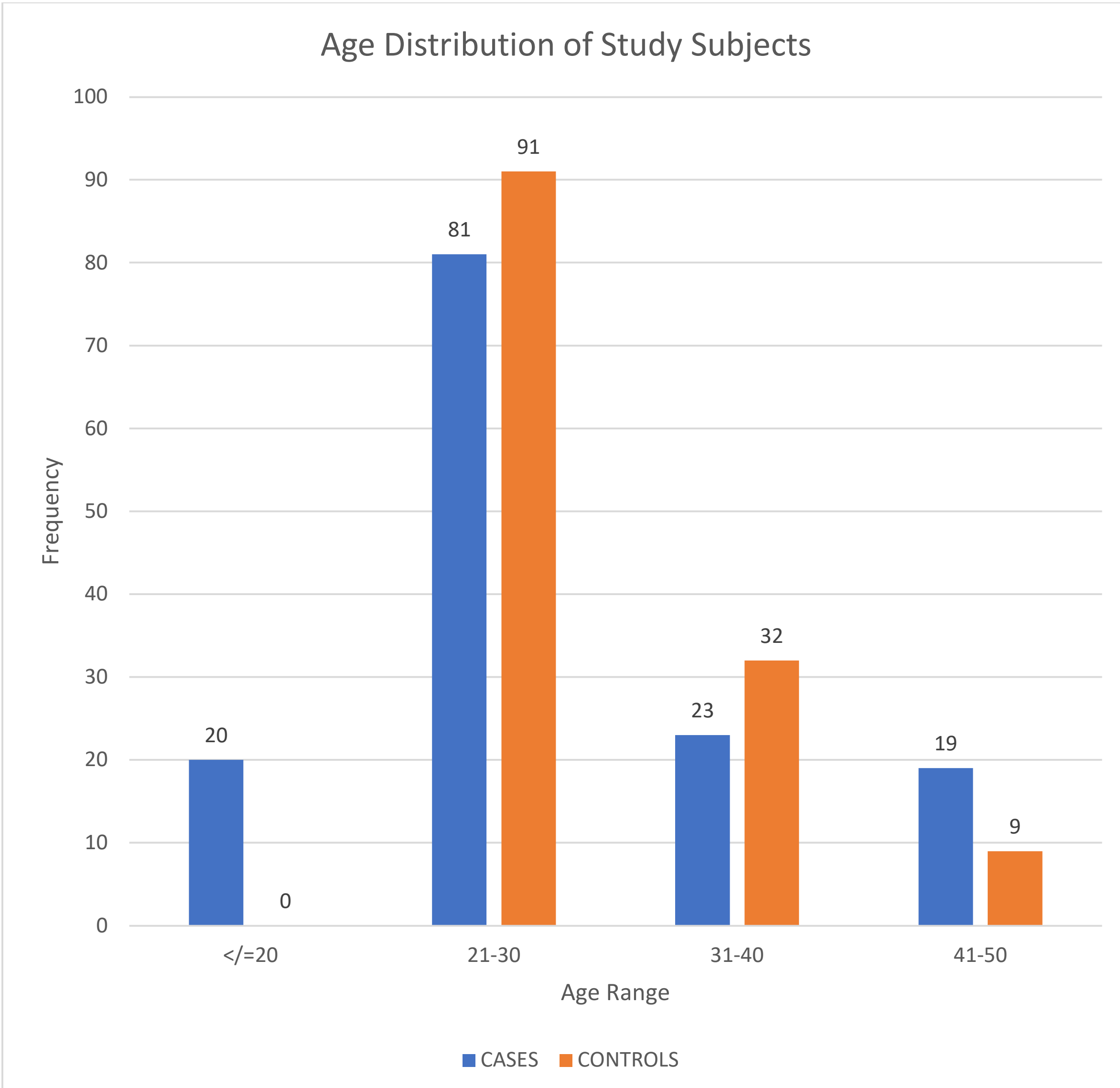


Figure 4.1: Age distribution of study participants

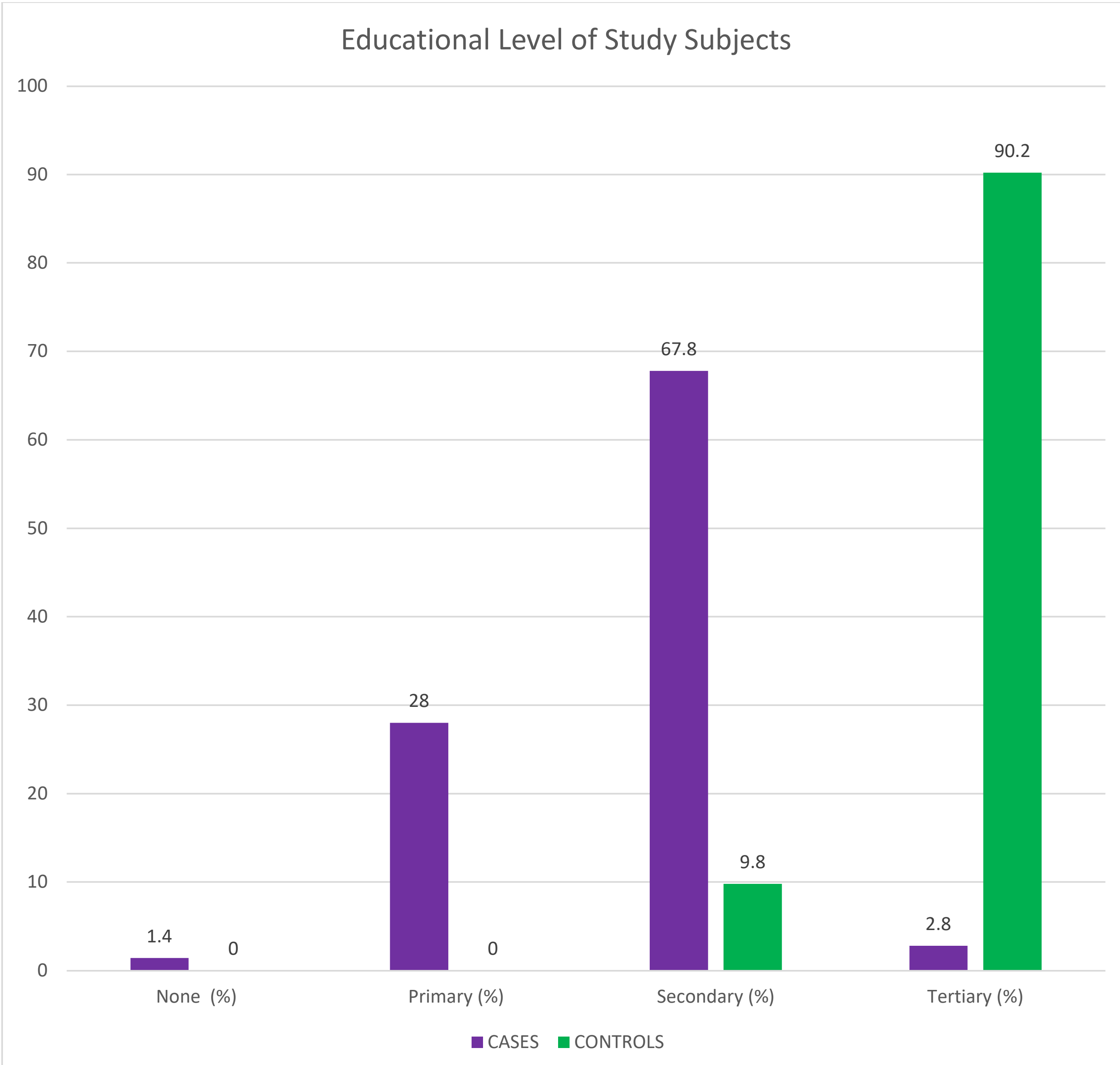


Figure 4.2: Educational level of study participants

4.4.1 Awareness of The Effect of Noise on Hearing and Health

Shown in Figure 4.3 below is a graph displaying the level of awareness of the effect of noise on hearing and health among cases. With regards to the awareness of the effect of noise on health, half of the cement block factory workers thought that excessive noise could affect one's health whilst 84.6% of the controls thought that noise had adverse effects on health. When asked to specify, of the cases, 34.3%, said noise could cause hearing loss, 22% and 27.3% thought that tinnitus and increased risk of workplace injury could each result from excessive noise exposure respectively whilst 17.5% were of the view that there could be annoyance as a result of too much noise in the work place. Seventeen factory workers, constituting 11.9% believed that all the listed effects could occur from over exposure to loud noise. Nearly half of the cases (48.3%) were not aware of any of the listed effects of noise on health.

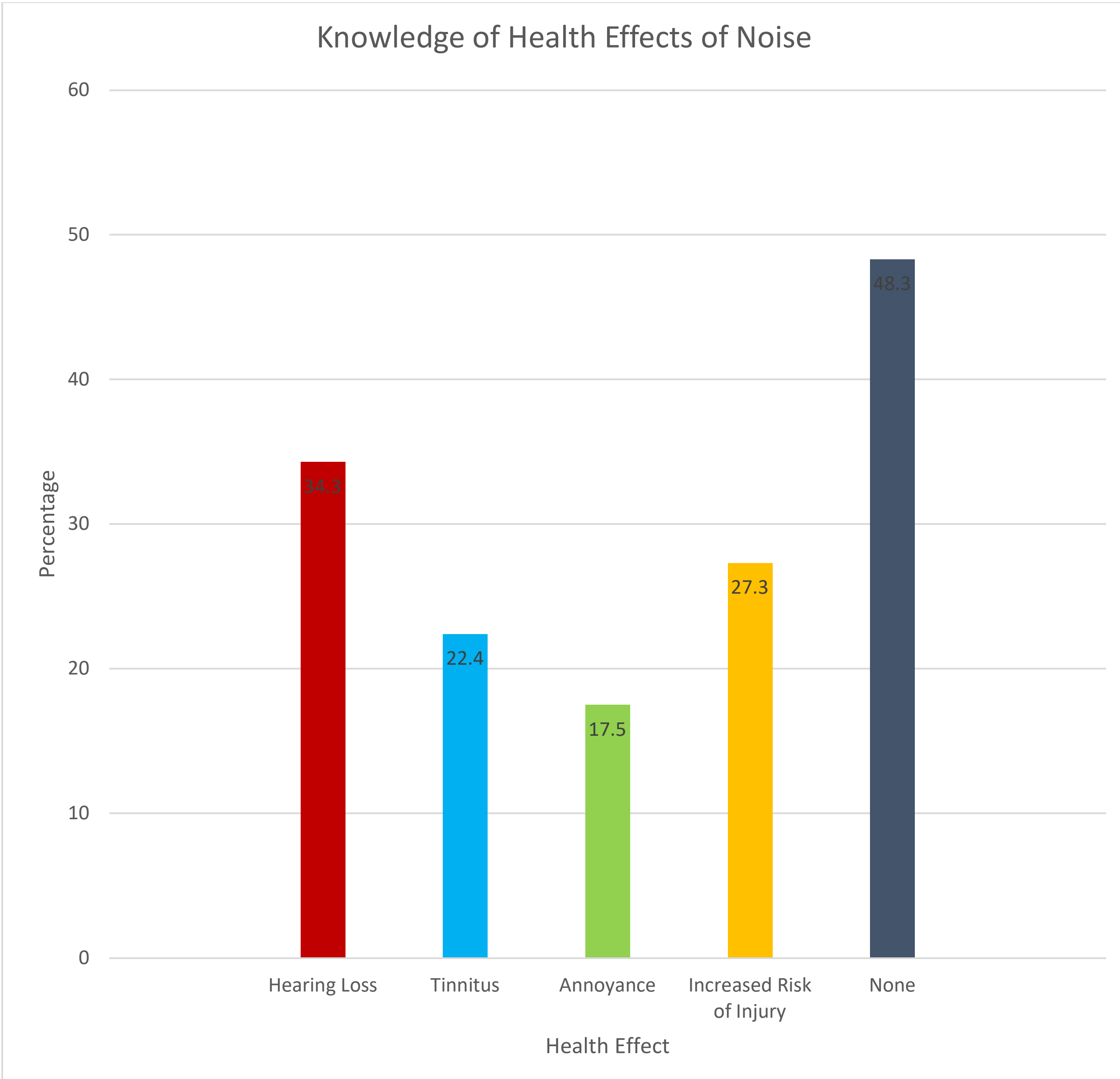


Figure 4.3: Knowledge of the health effects of noise among cases

On the other hand, of the 132 controls, only 15.2% were unaware of the effects of noise on health. Whereas 81.1% knew that excessive noise exposure could result in hearing loss, 41.7% were aware that there could be tinnitus as a result of high noise levels with 31.8% each knowing that annoyance and increased risk of workplace injury could be a consequence of extreme industrial noise exposure. Nearly 23% knew about all the effects of noise exposure on health.

All the cement block factory workers were of the opinion that they were exposed to excessive noise level at work whereas their counterparts within the hospital environment did not think the noise levels around them were high.

Self-reported hearing loss among cases was 22.4% as compared to 2.3% of controls with subjective hearing loss. Again, tinnitus was reported to be present by 42 (28.2%) cement block factory workers as against 3.8% among controls.

4.4.2 Hearing Protection Device Knowledge and Use

In this study, 53.8% of workers of the block factories knew about HPDs. Of the HPDs shown to participants, the commonest known was the ear muff, with nearly 63% of participants having seen one before, followed by the semi-insert devices known by 11.9% of the workers. None of the cases knew of electronic HPDs. Three of the block factory workers (2.1%) mentioned stuffing of polythene pieces or cloth as HPDs. Roughly forty-six percent (46.2%) did not know any of the devices presented.

Considering the use of HPDs, although all the cases were of the opinion that they needed to use an HPD, only 23 workers representing 16.1% used them. Of these who did use HPDs, the ear muff was the only type used.

Of the 83.9% who did not use the protective devices, cost of the devices was the commonest cited reason (39.4%), followed by unavailability of the equipment (28.7%). Thirteen percent (13.0%) had no reason for not using the devices. Figure 4.4 below shows the above.

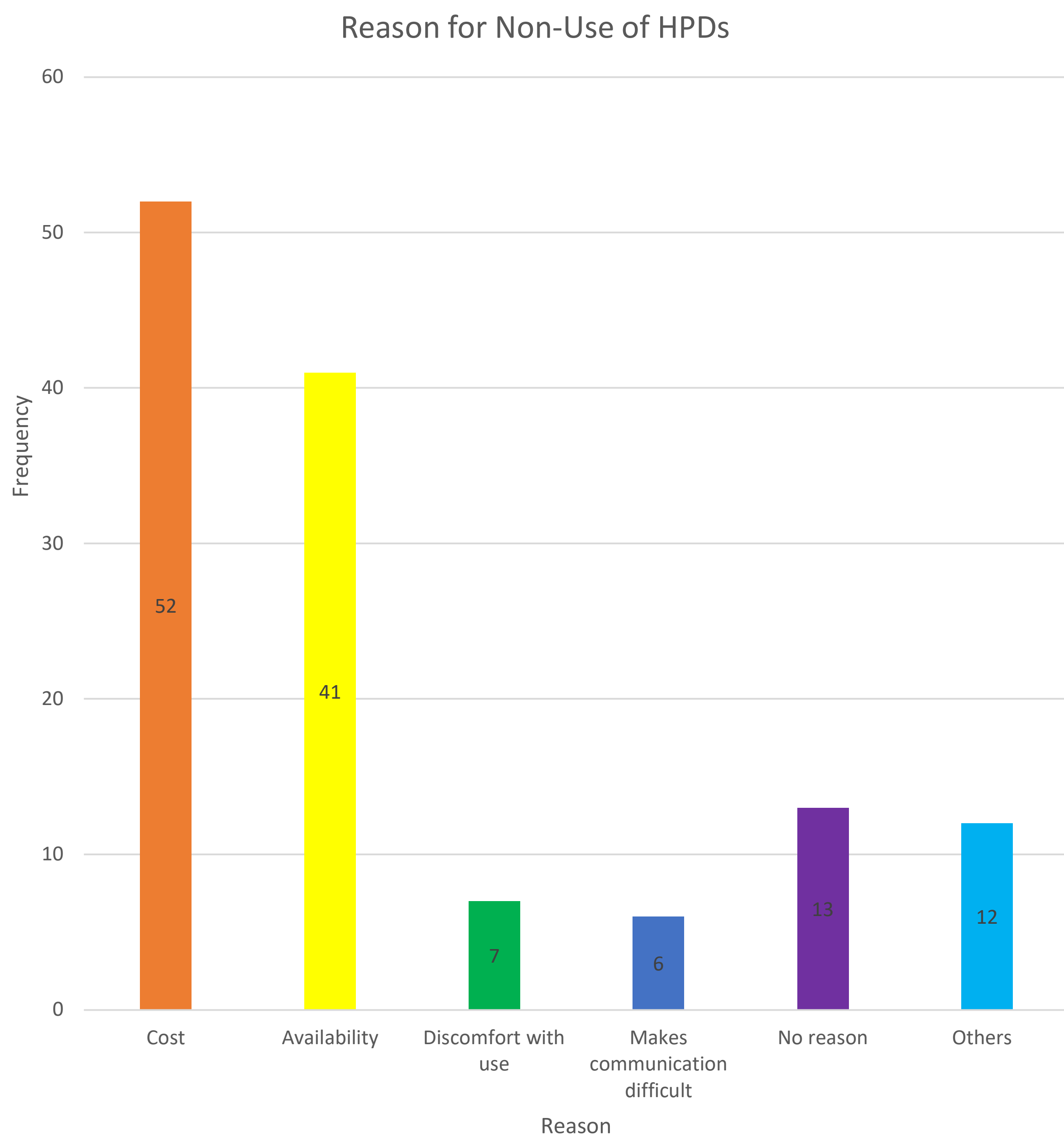


Figure 4.4: Reason for non-use of hearing protective devices

4.5 Noise Levels in Block Factories

Of the 19 block factories whose employees were involved in the study, 5 used the modern high yield block factory machines whilst 14 used the locally manufactured machines or the small sized China - made machine. The modern machines were of medium and large sizes depending on output of block units (8 and 12 respectively) whilst the locally manufactured machines were classified as small size being able to produce 2 units of blocks a time. There were foreign machines that also produced 1 piece of cement block at a time.

Noise levels in the block factories and those within the hospital environment were varied. When the machines were off, the mean work place environmental noise level in the block factories was 60.6dBA+/-7.1dBA. However, with the machine in operation maximum noise levels ranged between 91.1dBA to 104.1dBA for the small sized China-made machines, 91.2dBA to 101.3dBA for the medium sized Ghanaian manufactured machines and 103.2 dBA to 110.1dBA for the large sized China-made machines. The mean work place environmental noise levels when the machines were in full operation is outlined in Table 4.2 below:

Table 4.2: Noise levels of block factories at full operation

ID	MACHINE TYPE	MIN	MAX	Leq
1	China-S	89.3	94.6	91.2
2	China-S	93.4	104.1	97.4
3	China-S	87.0	91.1	89.1
4	China-S	93.7	98.9	96.1
5	China-S	90.4	97.7	95.6
6	Ghana	96.9	100	98.8
7	Ghana	101.3	104.1	103.7
8	Ghana	97.2	103.2	101.6
9	Ghana	93.0	97.3	95.1
10	Ghana	91.2	100.3	97.6
11	Ghana	98.3	102.8	100
12	Ghana	100.0	103.9	102.9
14	Ghana	93.9	105.7	100.3
15	Ghana	94.9	100.4	98.5
16	China -L	76.4	103.2	96.2
17	China-L	78.2	108.4	101.7
18	China-L	84.4	104.8	100.4
19	China -L	100.7	103.6	101.6
20	China-L	105.5	109.7	107.2

*Leq – Equivalent continuous level

Within the environs of KBTH, the noise levels ranged between 44.5dBA and 69.4dBA, with the highest peak being 87.9dBA. Overall, the mean range of sound levels in the different departments of KBTH was 50.2±5.2dBA to 61.9±6.3dBA.

4.6 Hearing Thresholds Using Pure Tone Audiometry Assessment

Shown in Table 4.3 below are the mean hearing thresholds of cases and controls at all frequencies examined, both for the conventional pure tone frequencies and the extended high frequencies. For all the frequencies, for both the right and the left ears the mean hearing threshold was higher among the block factory workers than the controls. This was statistically significant at majority (77%) of the tested frequencies for both ears.

Table 4.3: Mean hearing thresholds of participants

Frequency (Hz)	Ear	Mean (SD)		*p*-value
		Case (n = 143)	Control (n = 131)	
250	Right	13.5± 7.1	11.6± 6.1	.017
	Left	14.3± 7.2	12.9± 10.4	.181
500	Right	18.3± 5.6	15.7± 4.7	.000
	Left	18.5± 5.8	16.5± 10.4	.053
1000	Right	17.5± 5.0	14.8± 5.2	.000
	Left	17.5± 5.8	14.8± 8.4	.003
2000	Right	17.6± 6.6	13.9± 6.3	.000
	Left	17.3± 7.6	14.6± 11.9	.023
3000	Right	21.4± 10.4	14.5± 8.0	.000
	Left	21.9± 10.0	16.2±12.5	.000
4000	Right	19.7± 11.6	10.5± 7.7	.000
	Left	21.6± 11.9	12.9± 13.1	.000
6000	Right	21.9± 13.0	13.3± 10.1	.000
	Left	22.3± 12.3	16.0± 13.9	.000
8000	Right	19.5± 13.0	13.7± 11.6	.000
	Left	20.5± 14.1	15.6± 13.8	.004
9000	Right	13.7(13.5)	12.4(10.1)	.360
	Left	13.2±14.9)	11.7±11.2	.369
11200	Right	5.6±13.5	0.95±4.1	.000
	Left	6.9±14.5	1.9±8.3	.001
12500	Right	20.4±15.4	17.4±11.3	.061
	Left	21.2± 15.2	17.5±12.0	.025
14000	Right	18.8± 14.2	16.1±12.2	.098
	Left	20.9± 15.5	15.41±0.9	.001
16000	Right	16.1± 17.8	8.5±13.4	.000
	Left	17.1± 19.2	6.6±11.4	.000

4.6.1.1 Conventional Pure Tone Audiometry

Indicated in Tables 4.4a and 4.4b below are the frequencies of normal hearing and hearing loss at the tones for conventional pure tone audiometry and the pure tone averages of the cases and controls. To be noted is the fact that with increasing frequency – from 250Hz through to 8kHz, there was a steady rise in the number of subjects with hearing loss, both among cases and controls.

Within the block factory workers, whereas at 250Hz the hearing loss for the right and the left ears were 4.2% and 3.5% respectively, there was a sharp rise to 17.5% and 25.9% for the right and left ears respectively at 3kHz. This further increased to reach 22.4% and 25.2% respectively at 6kHz.

Also, with the controls whereas at 250Hz only 2 right and 4 left ears (1.5% and 3% respectively) had abnormal hearing thresholds, at 6kHz this had increased to 6.1% in the right ear and 8.3% in the left ear.

Considering the Pure Tone Averages (PTA_{5124}, PTA_{234} and PTA_{346}), block factory workers with hearing loss using the $PTA_{.5124}$ consisted of 9.8% of subjects for the right ear and 9.1% for the left ear. At PTA_{234} prevalence of hearing loss increased to 16.1% and 22.4% for the right ear and left ear respectively. This further deteriorated to 19.6% for the right ear and 28.7% for the left ear as calculated by the PTA_{346} (which used thresholds at 3,4 and 6kHz, the frequencies most affected by excessive noise exposure. For both ears, the frequency of hearing loss was 27 (9.4%) using $PTA_{.5124}$ and 69 (24.1%) using PTA_{346}.

Using the PTAs, among controls, prevalence of hearing loss was 0.7% for the right ear and 3.8% in the left ear for $PTA_{.5124}$. When calculated by PTA_{234}, it was 4.5% in the right ear, and 3.8% in the left. On the other hand, for PTA_{346}, hearing loss among controls was 6.8% for the right ear and 6.1% for the left ear. Overall, hearing loss for both ears (264) was 2.2% at PTA1 and 6.4% using PTA_{346}. This is shown in Figure 4.4b below.

Table 4.4a: Hearing thresholds levels using cPTA among cases

Freq/ kHz	Normal Hearing n (%)		Mild Hearing Loss n (%)		Moderate Hearing Loss n (%)		Severe Hearing Loss n (%)	
	Right	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Conv.								
.250	137(95.8)	138(96.5)	6(4.2)	5(3.5)	0	0	0	0
.5	137(95.8)	137(95.8)	6(4.2)	6(4.2)	0	0	0	0
1	141(98.6)	138(96.5)	2(1.4)	5(3.5)	0	0	0	0
2	134(93.7)	130(90.9)	9(6.3)	11(7.7)	0	2(1.4)		
3	118(82.5)	106(74.1)	18(12.60	37(25.9)	5(3.5)	0	2(1.4)	0
4	119(83.2)	111(77.6)	17(11.9)	26(18.2)	6(4.2)	5(3.5)	1(0.7)	1(0.7)
6	111(77.6)	107(74.8)	20(14.0)	31(21.7)	10(7.0)	2(1.4)	2(1.4)	3(2.1)
8	111(77.6)	106(74.1)	26(18.2)	31(21.7)	4(2.8)	3(2.1)	2(1.4)	3(2.1)
$PTA_{.5124}$	129(90.2)	130(90.9)	13(9.1)	11(7.7)	1(0.7)	2(1.4)	0	0
PTA_{234}	120(83.9)	111(77.6)	21(14.7)	28(19.6)	0	4(2.8)	0	0
PTA_{346}	115(80.4)	102(71.3)	19(13.3)	36(25.2)	8(5.6)	4(2.8)	1(0.7)	1(0.7)

Table 4.4b: Hearing thresholds levels using cPTA among controls

Freq/ kHz	Normal Hearing n (%)		Mild Hearing Loss n (%)		Moderate Hearing Loss n (%)		Severe Hearing Loss n (%)	
	Right	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
.250	130(98.5)	128(97.0)	2(1.5)	2(1.5)	0	0	0	2(1.5)
.5	131(99.2)	129(97.9)	0	0	1(0.8)	1(0.8)	0	2(1.5)
1	130(98.5)	127(96.2)	1(0.8)	2(1.5)	0	0	1(0.8)	3(2.3)
2	129(97.9)	128(97.0)	2(1.5)	1(0.8)	0	0	1(0.8)	3(2.3)
3	122(92.4)	125(94.7)	9(6.8)	4(3.0)	0	0	1(0.8)	3(2.3)
4	130(98.5)	125(94.7)	1(0.8)	3(2.3)	0	0	1(0.8)	4(3.0)
6	124(93.9)	121(91.7)	6(4.5)	5(3.8)	1(0.8)	3(2.3)	1(0.8)	3(2.3)
8	121(91.7)	120(90.9)	7(5.3)	8(6.1)	2(1.5)	1(0.8)	2(1.5)	3(2.3)
$PTA_{.5124}$	131(99.2)	127(96.2)	0	2(1.5)	1(0.8)	1(0.8)	0	3(2.3)
PTA_{234}	126(95.5)	127(96.2)	5(3.8)	2(1.5)	0	0	1(0.8)	1(0.8)
PTA_{346}	123(93.2)	124(93.9)	8(6.1)	8(6.1)	1(0.8)	0	0	0

Table 4.5 Hearing levels using cPTA among cases and controls

		Normal		Hearing Loss	
Frequency(kHz)	Ear	Case	Control	Case	Control
0.25	Right	137(95.8)	130(98.5)	6(4.2)	2(1.5)
	Left	138(96.5)	128(97.0)	5(3.5)	4(3.0)
.5	Right	137(95.8)	131(99.2)	6(4.2)	1(0.8)
	Left	137(95.8)	129(97.9)	6(4.2)	3(2.3)
1	Right	141(98.6)	130(98.5)	2(1.4)	2(1.5)
	Left	138(96.5)	127(96.2)	5(3.5)	5(3.8)
2	Right	134(93.7)	129(97.9)	9(6.3)	3(2.3)
	Left	130(90.9)	128(97.0)	13(9.1)	4(3.0)
3	Right	118(82.5)	122(92.4)	25(17.5)	10(8.0)
	Left	106(74.1)	125(94.7)	37(25.9)	7(5.3)
4	Right	119(83.2)	130(98.5)	24(16.8)	2(1.5)
	Left	111(77.6)	**125(94.7)**	32(22.4)	7(5.3)
6	Right	111(77.6)	124(93.9)	32(22.4)	8(6.1)
	Left	107(74.8)	121(91.7)	36(25.2)	11(8.8)
8	Right	111(77.6)	121(91.7)	32(22.4)	11(8.8)
	Left	106(74.1)	120(90.9)	37(25.9)	12(9.6)
$PTA_{.5124}$	Right	129(90.2)	131(99.2)	14(9.8)	1(0.8)
	Left	130(90.9)	127(96.2)	13(9.1)	6(4.5)
PTA_{234}	Right	120(83.9)	126(95.5)	21(14.7)	6(4.5)
	Left	111(77.6)	127(96.2)	28(19.6)	3(2.3)
PTA_{346}	Right	115(80.4)	123(93.2)	28(19.6)	9(6.9)
	Left	102(71.3)	124(93.9)	41(28.7)	8(6.1)

Shown in Tables 4.6a and 4.6b are the hearing loss prevalence calculated by the different PTAs among cases and controls for the right and left ears respectively. Prevalence for all three PTAs were significantly different between cases and controls with the exception of $PTA._{5124}$ in the left ear which showed no significant difference

Table 4.6a: Prevalence of hearing loss using pure tone averages for the right ear

	Hearing status	Group, *n* (%) Case	Control	*p*-value
PTA.5124	Normal	129(90.2)	131(99.2)	0.001
	Hearing loss	14(9.8)	1(0.8)	
PTA.5124	Normal	120(83.9)	126(95.5)	0.002
	Hearing loss	23(16.1)	6(4.5)	
PTA.5124	Normal	115(80.4)	123(93.2)	0.002
	Hearing loss	28(19.6)	9(6.8)	

Table 4.6b: Prevalence of hearing loss using pure tone averages for the left ear

	Hearing status	Group, *n* (%) Case	Control	*p*-value
PTA.5124	Normal	131(90.9)	127(96.2)	0.113
	Hearing loss	12(9.1)	5(3.8)	
PTA.5124	Normal	111(77.6)	127(96.2)	0.00
	Hearing loss	32(22.4)	5(3.8)	
PTA.5124	Normal	102(71.3)	124(93.9)	0.00
	Hearing loss	41(28.7)	8(6.1)	

Taking the better hearing ear into consideration, Figure 4.5 below displays the hearing prevalence with respect to the pure tone averages $PTA_{.5124}$, PTA_{234} and PTA_{346}. Among cases, there was 3.5% prevalence hearing loss in the better hearing ear at $PTA_{.5124}$ as against one control (0.75%). This increased to 14.7% among cases and 3% among controls at PTA_{346}.

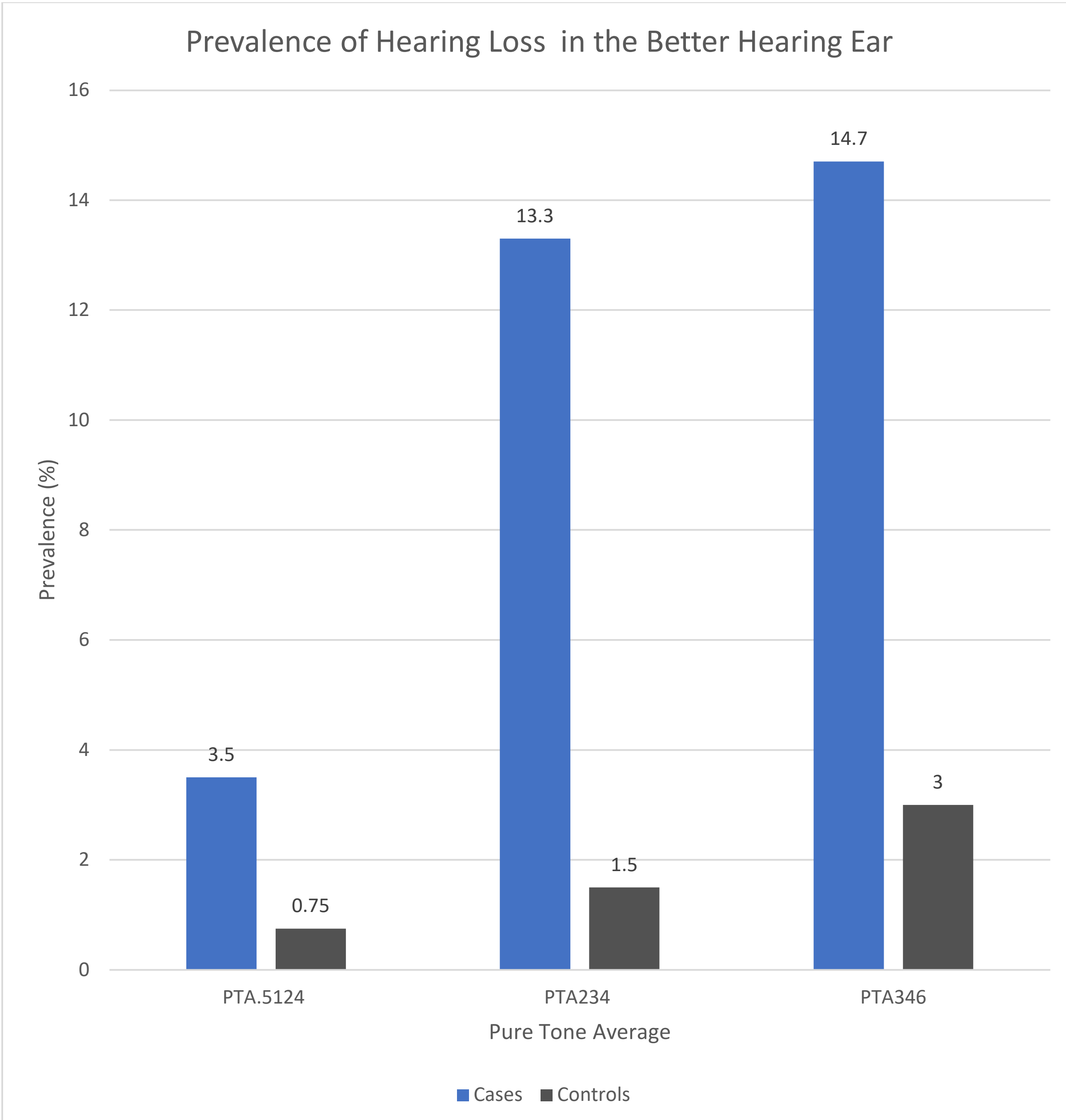


Figure 4.5: Prevalence of hearing loss in the better hearing ear of cases and controls

In Figure 4.6 below is the hearing loss prevalence by ear for both cases and controls. Among cases, hearing loss prevalence (PTA_{346}) in the better hearing ear was 14.7% but 3.0% among controls.

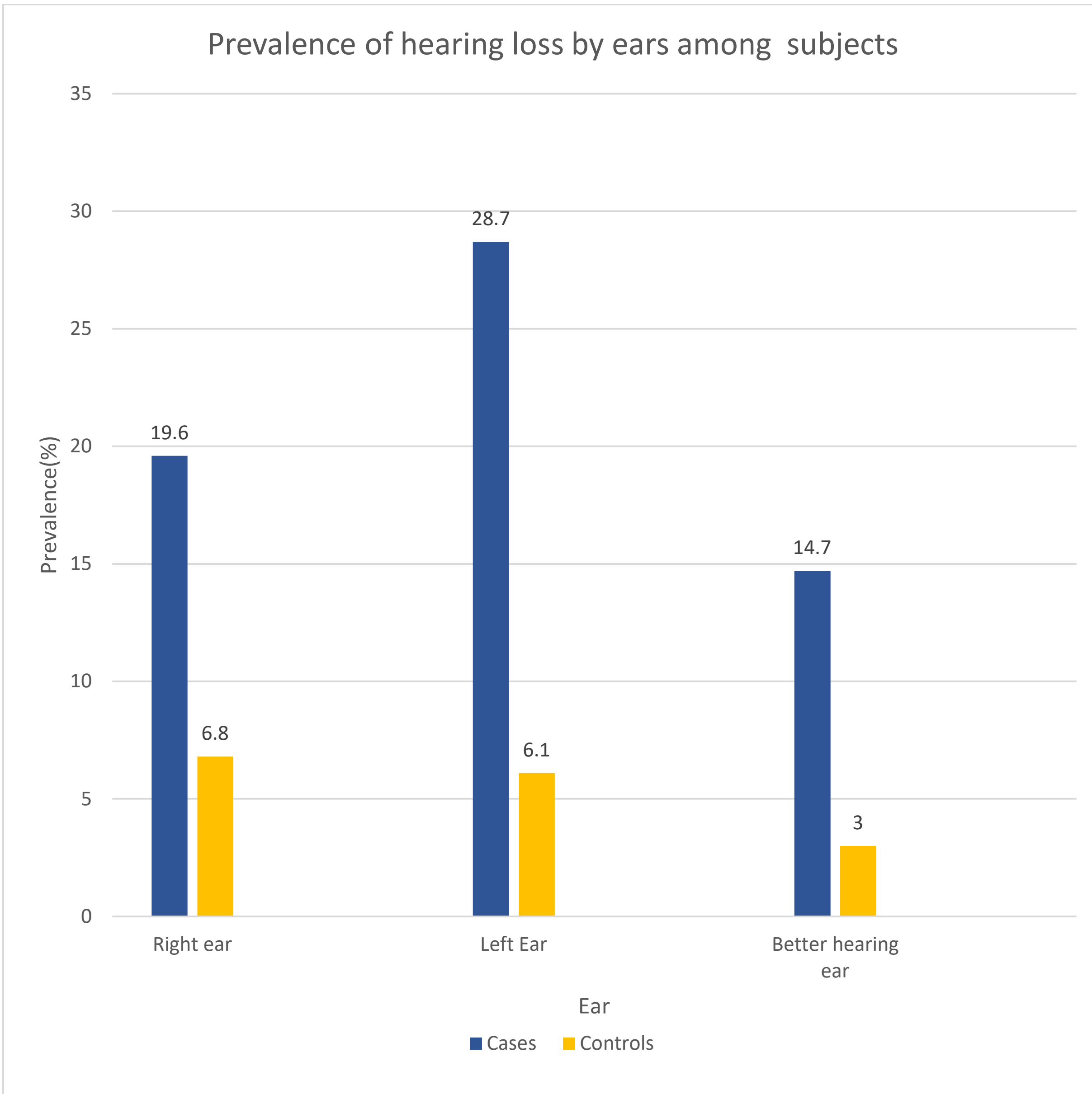


Figure 4.6: Hearing loss prevalence among subjects by ears.

Below in Table 4.7 are the grades of hearing loss in the better hearing ear for subjects. Seventeen cases (11.8%) had mild hearing loss in the better hearing ear whist 2.3% of controls had mild hearing loss in their better hearing ear. One control had severe hearing loss and 2.8% of cases had moderate hearing loss in their better ear.

Table 4.7: Grades of hearing loss in the better hearing ear

	Grade of Hearing loss, n (%)		
	Mild	**Moderate**	**Severe**
Cases	17(11.8)	4(2.8)	0
Controls	3(2.3)	0	1(0.8)

Shown in Figure 4.7 below is the prevalence of hearing loss using PTA_{346}, in view of work duration. As indicated, for up to 10 years of work duration, there was a rise in the percentage of the cases with hearing loss with increasing duration of years with 40% of those who had worked for 6 to 10 years having hearing loss in the better hearing ear. Of the few workers (9.8%) who had worked for more than 10 years, none had hearing loss.

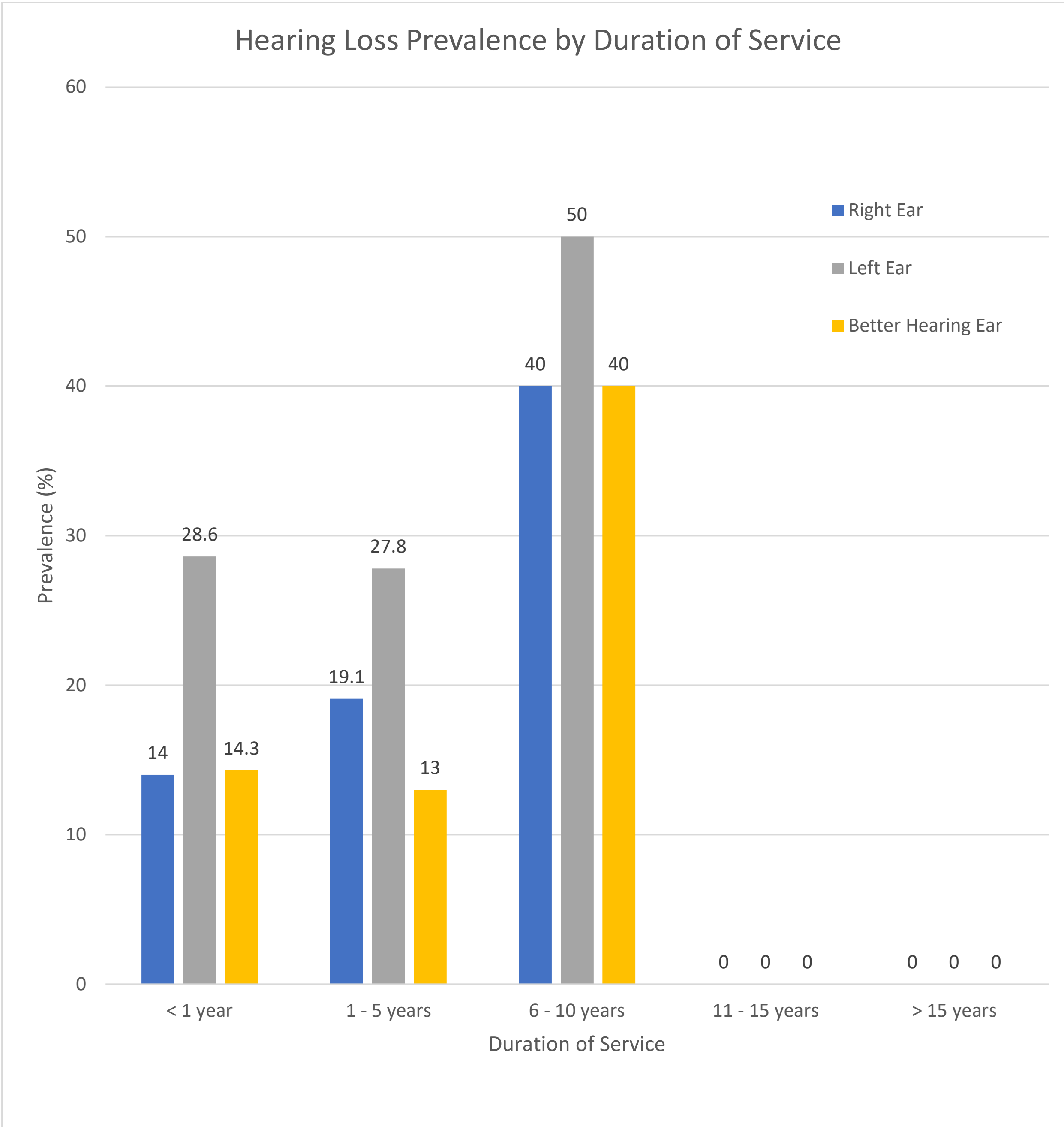


Figure 4.7: Duration of work and hearing loss among block factory workers

In Figure 4.8 below is a bar graph showing the percentages of hearing loss among the various job descriptions within the block factory workers: machine operators, labourers and others. Of the operators who represented 18.2% of the cases, 21.9% of them had hearing loss in the better hearing ear. For the labourers who constituted 75.5% of the factory workers, those with hearing loss in the better hearing ear was 13.2%. None of the workers within the “others” group had hearing loss so far as the better hearing ear was concerned.

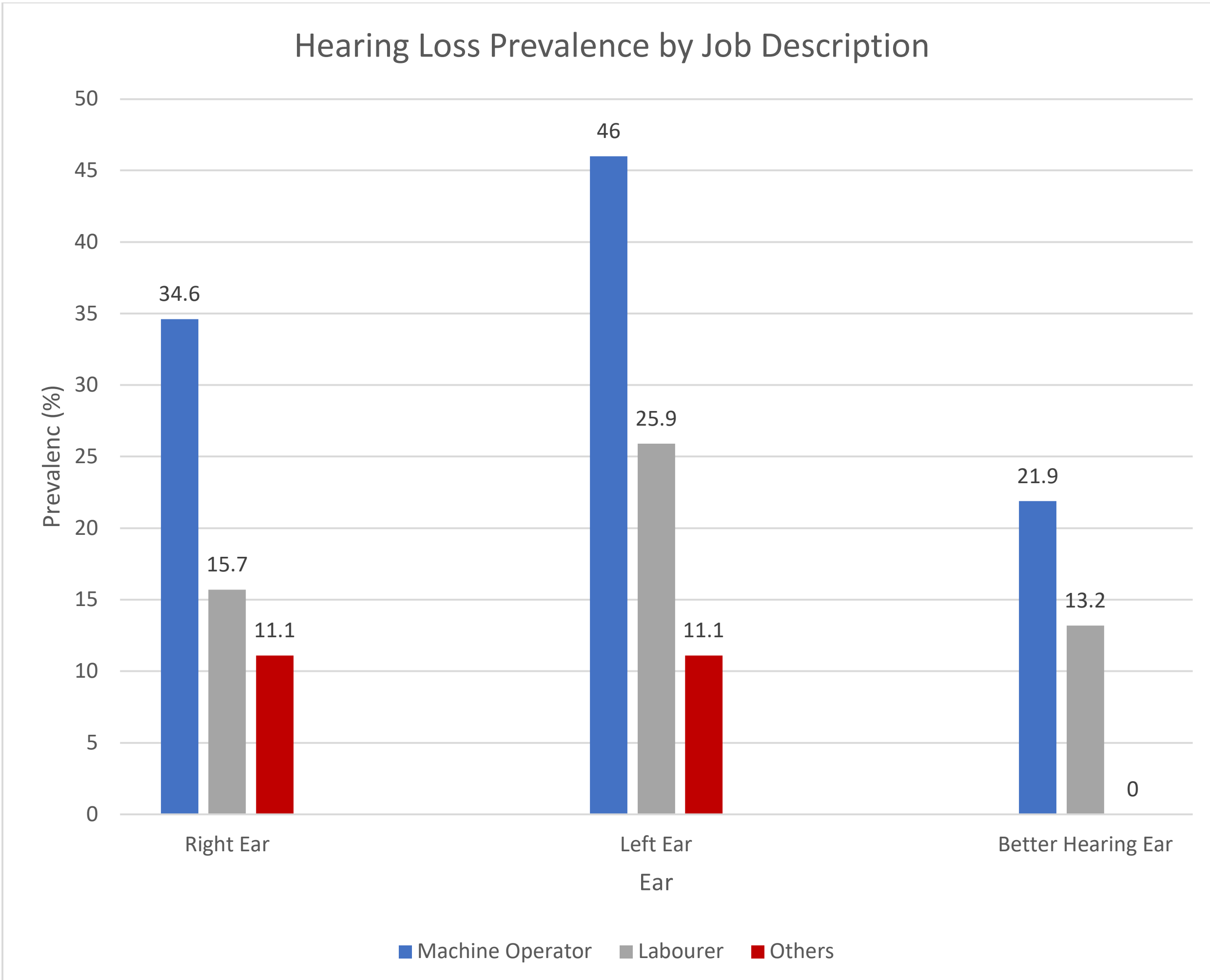


Figure 4.8: Job description and hearing loss among block factory workers

4.6.1 Audiometric Notch Distribution of Subjects

Shown in Table 4.8 below is the distribution of audiometric notches among subjects. In the right ear, at 3kHz, 12.6% and 3.8% of block factory workers and controls respectively had notches. The 4khz notches in that same ear was 5(3.5%) for cases and 1(0.76%) for controls. At 6kHz in the right ear 9.8% of block factory workers had a notch, whereas only 1(0.76%) control showed notching.

The distribution in the left ear indicated 11.9% and 1.5% at 3kHz for cases and controls respectively and 10.5% and 3.0% again for cases and controls respectively at 4kHz. The 6kHz audiometric notch was present in 9 (6.3%) of the left ears of block factory workers but none among the controls. With the exception of 4kHz notch in the right ear, there was a significant difference in the occurrence of audiometric notches between cases and controls for both ears.

Table 4.8: Audiometric notch distribution of subjects

Type of notch	Right Ear n (%)		*p*-value	Left Ear n (%)		*p*-value
	Cases	Controls		Cases	Controls	
3kHz	18 (12.6)	5(3.8)	0.008	17(11.9)	2(1.5)	0.001
4kHz	5(3.5)	1(0.76)	0.120	15(10.5)	4(3.0)	0.033
6kHz	14(9.8)	1(0.76)	0.001	9(6.3)	0	0.003

4.6.1.2 Extended High Frequency Pure Tone Audiometry

Exhibited in Tables 4.9a and 4.9b below are the frequencies of normal hearing thresholds and raised thresholds indicative of hearing loss for block factory workers and controls respectively. For both the noise exposed group and the unexposed group, the number of subjects with hearing loss increased from 9000Hz to 16,000Hz.

For the cases, at 9kHz, the percentage of hearing loss in both ears was 13.2%, increasing to 36.4% at 16kHz. Among the unexposed group, hearing loss was found in 8.0% at 9kHz and 11.7% at 16kHz for both ears.

Table 4.9a: Hearing thresholds levels using EHF audiometry among cases

EHF (kHz)	Normal Hearing n (%)		Hearing Loss n (%)	
	Right Ear	Left Ear	Right Ear	Left Ear
9	123(86.0)	125(87.4)	20(14)	18(12.6)
11.2	112(78.3)	108(75.5)	31(21.7)	35(24.5)
12.5	105(73.4)	101(70.6)	38(26.6)	42(29.4)
14	93(65.0)	91(63.6)	50(35.0)	52(36.3)
16	92(64.3)	90(62.9)	51(35.7)	53(37.1)

Table 4.9b: Hearing thresholds levels using EHF audiometry among controls

EHF (kHz)	Normal Hearing n (%)		Hearing Loss n (%)	
	Right Ear	Left Ear	Right Ear	Left Ear
9	122(92.4)	124(93.9)	10(7.6)	8(6.1)
11.2	115(87.1)	112(84.8)	17(12.9)	20(15.2)
12.5	114(86.4)	116(87.9)	18(13.6)	16(12.1)
14	121(91.7)	122(92.4)	11(8.3)	10(7.6)
16	115(87.1)	118(89.4)	17(12.9)	16(12.1)

At 12.5,14 and 16 kHz there was a significant difference in the hearing loss prevalence between cases and controls for both right and left ears($p<0.05$). At 9 and 11.2 kHz, the difference in hearing loss prevalence was not significant for either ear ($p>0.05$). This is shown in Table 4.10 below.

Table 4.10: Hearing loss prevalence using EHF among cases and controls

EHF (kHz)	Right Ear n (%)			Left Ear n (%)		
	Cases	Controls	*p*-value	Cases	Controls	*p*-value
9	20(14)	10(7.6)	0.08	18(12.6)	8(6.1)	0.065
11.2	31(21.7)	17(12.9)	0.055	35(24.5)	20(15.2)	0.053
12.5	38(26.6)	18(13.6)	0.008	42(29.4)	16(12.1)	0.00
14	50(35.0)	11(8.3)	0.00	52(36.3)	10(7.6)	0.00
16	51(35.7)	17(12.9)	0.00	53(37.1)	16(12.1)	0.00

4.6.2 Distortion Product Otoacoustic Emission Amplitudes

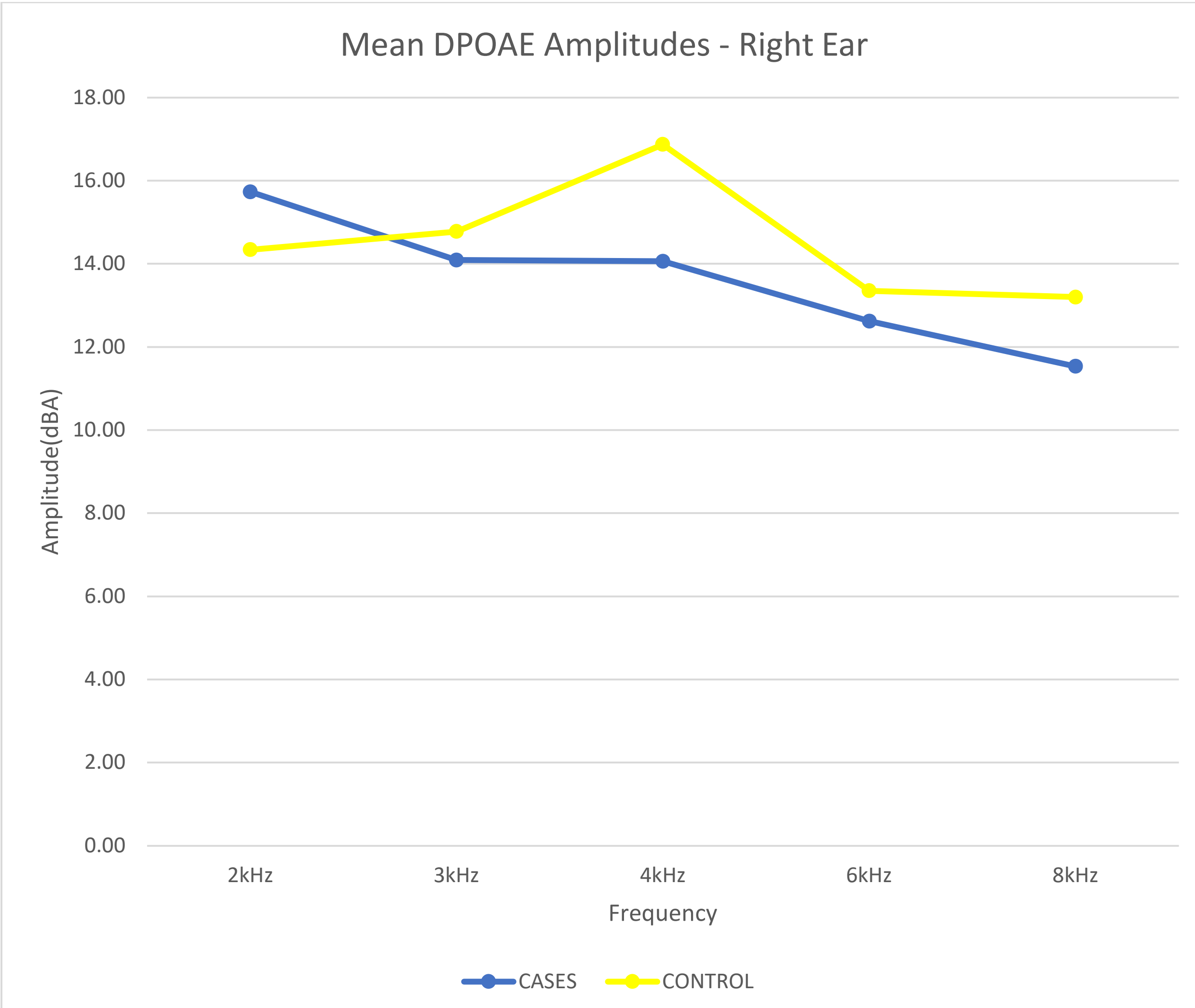


Figure 4.9a: Mean DPOAE amplitudes of study subjects (Right Ear)

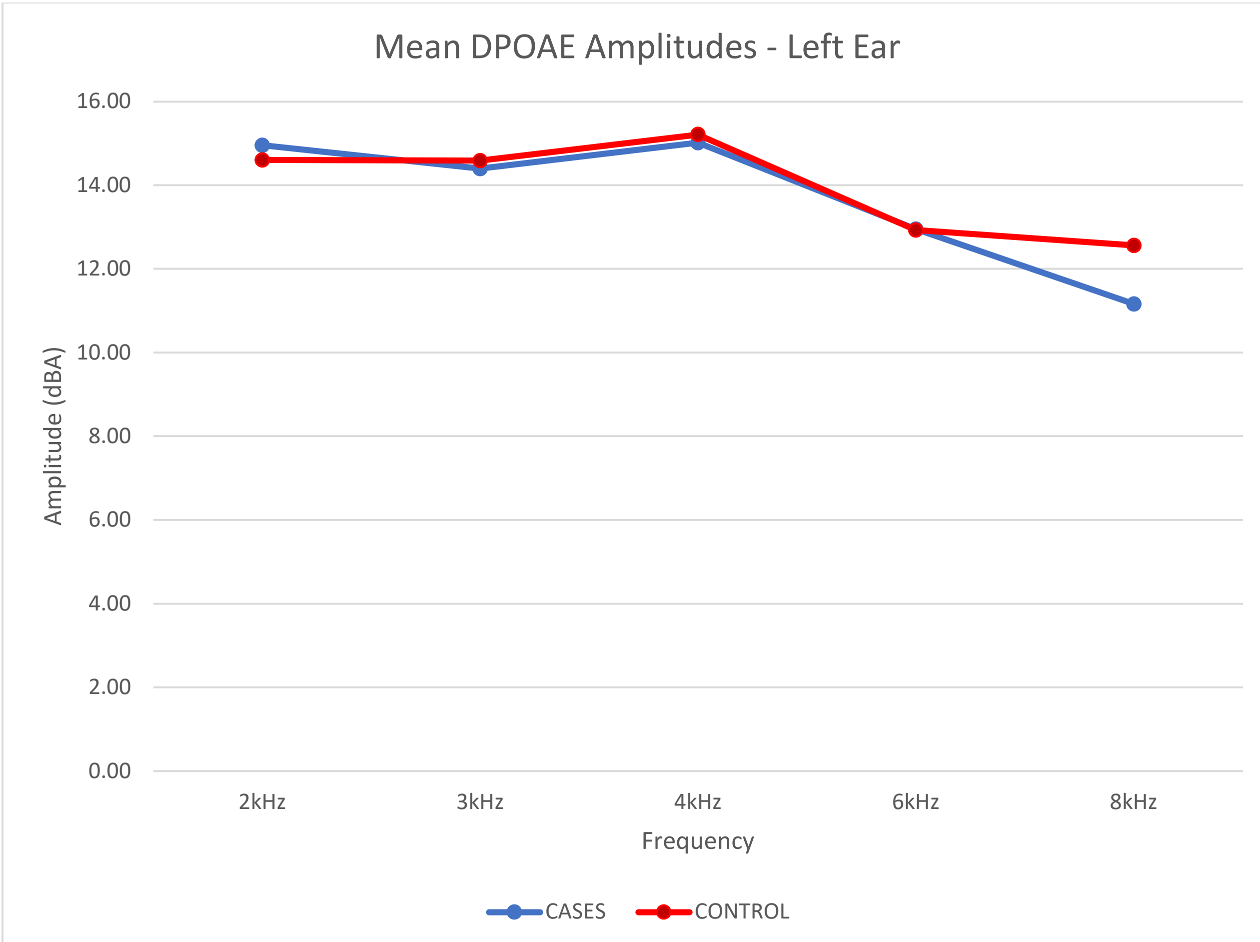


Figure 4.9b: Mean DPOAE amplitudes of study subjects (Left Ear)

Indicated in Figures 4.9a and 4.9b above are charts showing the mean DPOAE amplitudes for the right and left ears of cases and controls. Whilst the mean for the cases in the right ears showed lower values than that for the controls, in the left ears the means were similar.

In Table 4.11a below are the DPOAE amplitudes for cases and controls. These demonstrate increasing number of subjects with abnormal amplitudes with increasing f2 frequency tested. With 12.6% and 10.5% of cases having low amplitudes for the right and left ears respectively at 2kHz, this rises to 32.1% and 30.8% for the right and left ears at 8kHz respectively.

Among the control group, at 2kHz participants with abnormal amplitudes were 10.6% for both right and left ears. At 8kHz, this had increased to 20.5% for the right ear and 25.8% for the left ear. In all, DPOAE results showed a general trend of increasing frequency of abnormal amplitudes with higher pure tone testing.

Table 4.11a: DPOAE amplitudes of cases and controls

Frequency (kHz)	Ear	DPOAE amplitudes n (%)			
		Normal SNR (>10)		Low amplitude SNR (<10)	
		Cases	Controls	Cases	Controls
2	Right	125(87.4)	118(89.4)	18(12.6)	14(10.6)
	Left	128(89.5)	118(89.4)	15(10.5)	14(10.6)
3	Right	124(86.7)	116(87.9)	19(13.2)	16(12.1)
	Left	125(87.4)	117(88.6)	18(12.5)	15(11.4)
4	Right	120(83.9)	117(88.6)	23(16.1)	15(11.4)
	Left	129(90.2)	119(90.2)	14(9.8)	13(9.8)
6	Right	112(78.3)	115(87.1)	31(21.7)	17(12.9)
	Left	108(75.5)	112(84.8)	35(24.5)	20(15.2)
8	Right	97(67.8)	105(79.5)	46(32.1)	27(20.5)
	Left	99(69.2)	98(74.2)	44(30.8)	34(25.8)

*SNR – signal to noise ratio

Table 4.11b: Prevalence of low DPOAE amplitude among cases and controls

Frequency (kHz)	Ear	No. with low DPOAE amplitude		*p*-value
		Case	Control	
2	Right	17	14	0.737
	Left	16	14	0.877
3	Right	16	16	0.810
	Left	22	15	0.329
4	Right	25	15	0.150
	Left	15	13	0.861
6	Right	37	17	0.007
	Left	35	20	0.053
8	Right	50	27	0.007
	Left	42	34	0.503

In Table 4.11b, the prevalence of low DPOAE amplitudes among subjects is outlined. Both groups show increased prevalence with no statistical difference between the two groups ($p>0.05$) at all f2 frequencies tested

4.7 Comparison of Prevalence of Hearing Loss Between Audiological Assessment Methods and DPOAE

In Table 4.12 below, the prevalence of hearing loss detected by the various audiometry assessment methods as well as prevalence of low amplitudes of DPOAEs of subjects are outlined

For both cases and controls, conventional audiometric average using $PTA_{.5124}$ (using thresholds at 500,1000,2000 and 4000Hz) gave the lowest hearing loss prevalence of 9.1% for either right or left ear (block factory workers) and 0.7% and 4.2% for the right ear and left ear respectively among controls. This was followed by the prevalence using $PTA_{234.}$ Prevalence of hearing loss by PTA_{346} was significantly higher than that by the two other pure tone averages.

The highest recorded prevalence among both cases and controls for pure tone audiometry was for the EHF for which 41.3% and 41.9% for the right ear and left ear respectively were recorded for the cases. For the controls 11.9% and 17.5% prevalence hearing loss was recorded for the right and left ears respectively.

Table 4.12: Prevalence of hearing loss and low DPOAE amplitudes among cases and controls

Type of test	Ear	Hearing loss, N (%)	
		Cases	Controls
PTA (500,1000,2000,4000Hz)	Right	13(9.1)	1(0.7)
	Left	13(9.1)	6(4.2)
PTA (2000,3000,4000Hz)	Right	23(16.1)	6(4.5)
	Left	32(22.4)	5(3.8)
High frequency average- PTA (3000,4000,6000Hz)	Right	27(18.9)	9(6.8)
	Left	42(29.4)	8(6.1)
Extended high frequency (9000 – 16000Hz)	Right	59(41.3)	17(11.9)
	Left	60(41.9)	25(17.5)
DPOAE (2000 – 8000Hz)	Right	61(42.7)	27(20.5)
	Left	62(43.4)	34(25.8)

Again, when PTA (PTA_{346} and EHF) was compared with DPOAEs, cases recorded significantly higher prevalence of abnormal DPOAEs than conventional pure tone audiometry or EHFA. Whereas prevalence by cPTA among cases was 18.9% and 29.4% for the right and left ears respectively, low DPOAE amplitude was recorded in 42.7% and 43.4% for the right and left ears respectively ($p < 0.05$). this is shown in Table 4.13 below.

Table 4.13: Comparison of hearing assessment methods among cases

Type of test	Hearing loss, N (%)	
	Right ear	**Left ear**
High frequency average- PTA (3000,4000,6000Hz	27(18.9)	42(29.4)
Extended high frequency (9000 – 16000Hz)	59(41.3)	60(41.9)
p-value	0.00	0.00
High frequency average- PTA (3000,4000,6000Hz	27(18.9)	42(29.4)
DPOAE (2000 – 8000Hz)	61(42.7)	62(43.4)
p-value	0.00	0.00
Extended high frequency (9000 – 16000Hz)	59(41.3)	60(41.9)
DPOAE (2000 – 8000Hz)	61(42.7)	62(43.4)
p-value	0.00	0.00

CHAPTER FIVE

DISCUSSION

5.1 Introduction – Demographic Data

Among the Ghanaian population, block factory work has been a male only occupation, with female involvement only in the modern set up where high output factories employ women in the role of secretaries and other administrative roles within the small attached administrative offices. These women are not involved in the direct work of moulding, loading and packing of blocks done by the labourers and operators of the block factories. On the other hand, within the hospital set up, both among the clinical and non-clinical staff, female workers form a considerable proportion of workers. These were demonstrated in this research, where of the 143 block factory workers, all but one were males (99.3%) whereas among the hospital staff, males and females consisted of 71.2% and 28.8% respectively. This was similar to the findings of Kitcher et al[5] who found 97.9% of workers in a stone crashing company being males. Other works done in settings where intensive physical labour is required have also shown male dominance among the worker population.[2,21,85,118] This may be explained by the fact that the intensive physical labour required for work in these industries lead to male predominance as well as sociocultural practices which encourage males to engage in these occupations rather than females. Considering the controls , the findings of this work differed from that of Kitcher et al[5] who recorded 83.3% of hospital staff being females as against 28.8% from this study. This is a result of the deliberate attempt by the investigator to increase the male proportion of controls to enable comparisons so far as sex was concerned.

Of all the participants in this study, age range was 18 to 50 years. Of these, majority were of the 21 to 30 years age range, representing 62.5%. Those who were 20 years or below constituted the least (7.3%), followed closely by subjects aged between 41 to 60 years who formed 10.2% of the study participants. Taking into consideration, the block factory workers, the youngest was 18 years whereas the oldest was 50 years. Their mean age was 29.3 years ± 9.2 years. More than half of them (56.7%) were aged 21 to 30 years. The age group forming the least of the group was those 41 to 50 years and above being 13.3% of the cases. This was however close to those 20 years and below who formed 14% of the cases. The mean age for the cases in this study appears to be lower, compared to several studies done in occupational NIHL.[21],[118-4] example, whilst the mean age of study participants in the study by Aliyu et al[119] who investigated NHIL in subjects in a cement factory was 37.4±8.5 years, that for Gyamfi et al[21] was 41.7 years.

However, with regards to the study by Arthur[52] also among cement factory workers, though the mean age of participants was higher at 33.9±10.21 years, majority of them were of those under 29 years, similar to the finding in this study. This could be due to the fact that work in the cement block factory is heavy manual work with little automation, especially among those in the traditional factories were most of the work is done manually. This therefore requires a more youthful workforce who can meet the physical demands needed at these block factories. An additional factor could be the fact that the block factory work is used by many of the young people as a means to raise funds to meet the financial demands required for apprenticeship in other fields or to pay for fees for higher education. Once these funds are raised majority abandon the work. The age distribution of the controls was similar to that of the cases, largely due to the matching of their ages to that of the controls for fair comparisons on findings so long as age is concerned.

Educational status varied considerably among cases and controls in this study. Of the 143 block factory workers, only 4 had had tertiary education with these being one proprietor and 2 university students who worked in the block factory to support their education. This was in sharp contrast to the controls of whom 90% were of tertiary education level. Nearly all (97.2%) of the cases had had education up to senior high school level or equivalent and below. This level of education among cases was similar to that found by Mandeep in Kenya[13] who had only 11.5% of workers in a steel rolling mill having had tertiary education with 88.5 % having had secondary education or lower. Of these, those with tertiary education had been with the administrative non-production unit. This is not surprising, since the work at the block factories required little training or technical know-how, merely requiring manual labour. Only a few operators who run the block factory machines were needed with even this requiring little training. On the other hand, the controls were mostly professionally trained personnel, with only a few such as the security personnel and server at the canteen having the less need for technical training and hence could be employed with senior high school level of education. Thus, most controls had had tertiary education to prepare them for the delicate duties their work required.

Job description among the block factory workers were categorised into three: Machine operators, labourers and others (consisting of supervisors/managers, secretarial staff, mechanics, welders and drivers no directly involved in the making of the cement blocks). These categories formed 18.2%, 75.5% and 6.3% of the cases respectively. This proportion of machine operators closely matches that found by Kitcher et al[5] whose investigation of a stone crashing company for NIHL showed 21.42% were machine operators. In their case however, the administrative staff formed 16.4% which is much higher than what was recorded in this study with only 6.3% forming part of the staff not directly involved in the block manufacturing. This could be because whereas the stone crashing company was an organised formal sector organisation, requiring well established administrative section to run its affairs, the several block factories involved in this study were not formally organised, with many without offices that run their affairs. The proprietor was even occasionally involved in the hard labour work himself or worked alone without the other administrative staff needed for established organisations.

With the controls, categorisation of the staff into clinical and non-clinical staff gave 60.6% being of the former category and 30.4% being the latter. The majority of controls being clinical staff can be explained by the fact that the hospital in general had a higher number of staff involved in the core business of the hospital work with a clinical to non-clinical staff ratio of 5:3.[115]

Many studies done in occupational NIHL has yielded mean duration of service of cases to be greater than 10years.[2,17,117] This study however recorded a mean duration of service of 3.0 ±3.2 years. This was closest to the mean duration of work of 5 years recorded by Nyarubeli et al in their work among iron and steel workers in Tanzania.[120] This comparatively shorter duration of service could be explained by the fact that many were temporary casual workers, using the block factory service as a source to raise funds for other purposes. A few who were mainly the machine operators were those whose vocation was block factory running. Duration of service among controls was similar to that of cases at a mean of 4.4 ± 3.57 years and this can be accounted for by the age matching of controls with cases leading to younger participating controls with shorter duration of service.

With an average number of hours per day of 8.1±0.6hours per day, the cases had a weekly mean working hours of 51.6±6.4 hours resting only one day a week. This was not too different in the work by Kitcher et al however who noted 9 hours of work a day by market mill workers.[17] The controls however worked for fewer hours with mean working hours per week of 42.5 ±7.2 having relatively more rest days (1.8 days) than the cases (1 day).

5.2 Knowledge on the effects of noise on health

Excessive noise is a nuisance and prolonged exposure to it irritating. However, the health effects of noise with more dire consequences may be lost on some individuals. When compared to the studies by Kitcher et al[5], Arthur (2019)[52] and Kanji et al (2019)[10] who had 87.5%, 86.4% and 82% of cases respectively knowing that excessive noise could have adverse effects on health, the 51.7% of the cases in this study knowing about the health effects of noise appears low. This is similar to findings by Kitcher et al in another informal setting of market mill workers who had 54.5% awareness of the effect of noise on health. However, in yet another study by Ahmed et al[121], an even lower percentage of only 4.1% of workers were aware that noise could adversely affect health.[121] With nearly 85% of controls knowing that excessive noise can be detrimental to health, the explanation could be the much higher educational level among controls who were also health workers.

5.3 Knowledge and use of Hearing Protective Devices

In most formal industrial set ups, there are legal requirements by labour organisations to ensure safety for the workers with ear safety not being excluded. Industries are required to provide education on HPDS and enforce their use among employees.[112] This will explain the high knowledge of HPDs reported by Tantranont et al (77.9%), Kanji (≈ 100%) and Ologe et al (92%)[10,109,113] Considering the largely informal nature of the industrial setting of the cement block factories with lack of management policies and implementation of labour rules, it was not surprising that nearly half (46.2%) of the workers were unaware of HPDs and their use.

With regards to the use of the HPDs only 23 workers, representing 16.1% of the cases used them in this study. This low HPD usage is similar to findings by Ahmed et al, Ologe et al and Omokhodian et al with 13.3%, 7.6% and no use of HPDs respectively as per their investigations.[16,121,122] Use of HPDs in the South African mines were recorded to be higher – 50% by both Kanji et al and Hansia et al, although these were still much lower than the percentages of workers who knew about the HPDs and the benefits of their use.[10,112] Taking the reasons for non-use of HPDs into perspective, whereas discomfort with use and interference with communication were the foremost reasons given by Hansia et al[112], in this study cost of the device followed by unavailability of the equipment were the reasons given in this study. Other reasons were given by Arthur[52] for lack of use of HPDs and these were lack of know-how for the use of the device (39.2%) and HPD use being unnecessary(14.4%) .[52]

5.4 Noise levels in industry

Regulations concerning noise levels in industries so far as workforce exposure has been spelled out by the Environmental Protection Agency of Ghana which also has the mandate to ensure that these are enforced. Though this may be happening in the formal sector, it may not apply to the informal sector with workers exposed to hazardous noise and other occupational and safety health issues.[123] Maximum noise levels measured in this study on the premises of the block factories when machines were fully operational ranged between 91.9dBA and 105.7dBA (mean of 100.3dBA±4.1dBA) for the traditional block factories, whereas in the modern high output factories it ranged between a minimum of 76.4dBA to a maximum of 109.7dBA (mean maximum level of 105.9dBA± 2.9dBA). These were the levels of noise that operators were exposed to due to they being close to the block making machine, the source of noise. In the traditional block factories, the labourers had similar noise exposure.

These maximum noise levels that the workers are exposed to over prolonged hours, albeit, in pulses are way above that known to be safe and permissible.[87,88] This excessive industrial noise exposure among workers with low use of hearing protection devices is similar to noise levels found in the Ghanaian industries both formal and informal[17–19] and in other international industrial settings.[9,87,89] This occurrence is of concern especially in the informal sector where there appears to be no one enforcing the safety measures and also considering the young population at risk of ear injury among the block factory workers. In the high output factories, however, the labourers and other workers were exposed to much lower sound levels. This is because whilst some ferried in sand or quarry dust to the mixing machine, others who transported the moulded blocks spent a considerable length of time away from the noisy moulding machine. These labourers were therefore exposed to noise levels ranging from 52.0dBA to 83.7dBA. These levels, lower than that which the operators were exposed to, were also within range of permissible noise levels by law. However, at a mean of 67.9dBA, it was still higher than noise exposure of controls.

Of consolation however is the fact that majority of these workers are only transiently working in this environment. Compared to the controls whose work environment had mean levels of 50.5dBA±5.2dBA minimum and 61.9dBA ± 6.3dBA it was evident that their levels are well within safe levels with no cause for concern so long as industrial noise exposure is concerned. This level of noise was similar to that recorded by Kitcher et al in different settings.[5,17]

5.5 Hearing loss prevalence using conventional Pure Tone Audiometry

Hearing loss prevalence among block factory workers was higher than controls by all assessment methods used. This difference was more marked with increasing frequency of sound. This attests to the fact that noise exposure affects the higher frequencies more than the lower frequencies and excessive noise exposure led to decreased hearing sensitivities more marked in the higher frequencies. This is demonstrated by a hearing loss prevalence of 9.1% using $PTA_{.5124}$ in the worse hearing ear of block factory workers lower than a prevalence of 22.4% at PTA_{234} and deteriorating further to 28.7% using PTA_{346}.

This is in agreement with findings by Arthur who recorded a prevalence of 7.6% and 22.7% hearing loss at PTA_{512} and PTA_{346} respectively in the worse hearing ear of her subjects. In the better hearing ear of cases this similar pattern of increasing prevalence of hearing loss when using higher frequencies in the determination of the pure tone average. Thus, the better hearing ear recorded prevalence of 3.5%, 13.3% and 14.7% at $PTA_{.5124}$, PTA_{234} and PTA_{346} respectively. For all three pure tone averages computed in the conventional audiometry frequencies, the difference in hearing loss between cases and controls was statistically significant ($p<0.05$) except for the prevalence of the left ear $PTA_{.5124}$ which showed no significant difference between cases and controls ($p=0.113$).

With a hearing loss prevalence in the better hearing ear of 14.7%, it is surprising that 22.4% of cases reported subjective hearing loss. However, since the ear with the hearing loss was not specified by subjects, they may have been reporting on the worse ear, rather than their overall hearing ability.

NIHL has been largely associated with a 4kHz audiometric notch and valuable in its diagnosis.[124] However, 3kHz and 6kHz notches have also been described though the latter is variable with limited importance.[124] In this study, the highest prevalence of 4kHz audiometric notches was obtained in the left ear of block factory workers at 10.5% whereas for controls it was 3.0%. overall, majority of audiometric notches were recorded at 3kHz among cases. This is contrary to the findings by Kitcher et al[17] who classically had majority (16.8%) of subjects with an audiometric notch at 4kHz. Investigations by Osei-Lah and Yeoh , like Kitcher et al, also found 4kHz notches to be more prevalent than 3kHz notches.[125] However, it is significant to note that in this study, majority of 4kHz audiometric notches were in the left ears of cases considering that there was a greater prevalence of hearing loss in that ear for that group. The higher prevalence of 3kHz notches may be due to the tone of noise produced by the block factory machines which may be typically injurious to the portion of the cochlear associated with the 3kHz hearing frequency. The difference in the presence of an audiometric notch between cases and controls was statistically significant ($p<0.05$) except at 4kHz in the right ear ($p=0.120$).

5.6 Hearing loss prevalence using Extended High Frequency Pure Tone Audiometry

Many investigations done have highlighted the ability of EHF audiometry to detect hearing impairment earlier than conventional pure tone audiometry. In this study this was revealed owing to the higher prevalence of hearing loss obtained at the EHFs than using the conventional PTA averages. Among block factory workers, there was a higher prevalence of hearing loss by EHF than conventional PTA and this difference was significant for both the right and left ears ($p=0.00$)This confirms the findings of the studies by Rodriguez-Valiente et al, Kumar et al and Mehrparvar et al who also found higher prevalence of hearing loss detected by EHF audiometry as compared to cPTA. [35,57,117] the frequencies with the highest prevalence of hearing loss were 14kHz and 16kHz, at 36.3% and 37.1% respectively. This is consistent with findings by earlier studies.[117,126,127] Contrary to the finding in this study, Laffoon et al found no significant difference between the hearing loss prevalence using cPTA and EHF audiometry.[62] Neither did Han et al in their comparison of EHF and cPTA among noise exposed workers.[128]

5.7 Hearing loss prevalence using DPOAE

Otoacoustic emission measurements have been touted to be better able to detect hearing loss at an earlier time than cPTA and show reduced amplitudes even in the presence of normal hearing thresholds by cPTA.[63,64] This study found reduced DPOAE amplitudes in at least 1 frequency in 42.7% of right ears and 43.4% in the left ear. This was significantly higher than the prevalence of hearing loss calculated using all three pure tone averages – $PTA_{.5124}$, PTA_{234} and PTA_{346} ($p=0.00$). This agrees with findings by several authors.[36,66,76] Other authors have however disputed this, based on their investigations.[69,71]

Worth mentioning is the occurrence of a high prevalence of low amplitude of DPOAE among controls. Recording prevalence of 28.8% for the right ear and 34.8% for the left ear (31.8% for both ears), whilst maintaining a low prevalence of hearing loss by conventional audiometry brings to light the findings of Marshal et al[72] who found reduced OAE amplitudes in subjects with otherwise normal pure tone threshold. This group however had had a brief period of exposure to impulse noise whereas the controls in this study were not noise exposed. A possible explanation could be the exposure to high levels of "covert" noise among the control population in this study. This occurs, for example, with the upsurge in the use of personal listening devices,[103] especially those used in connection to mobile telephones for receiving calls as well as listening to music. This calls for investigation of this phenomenon of PLD use and its effects on hearing among the Ghanaian population.

In all, DPOAE measurements recorded significantly higher prevalence of hearing abnormalities as compared to PTA both conventional and extended high frequency among subjects in this study.

5.8 Limitations of the Study

This study was a cross sectional study and so could not determine the progression of noise induced hearing loss among the study population.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The prevalence of hearing loss by conventional pure tone audiometry among block factory workers for both ears was 24.1%. For the better hearing ear, prevalence among cases was 14.3%. For the controls, hearing loss prevalence was 6.1% using conventional pure tone audiometry in both ears but 3% for the better hearing ear. This prevalence was significantly higher using EHFA which was 41.6% among cases and 15.9% among controls. With regards to DPOAE, 43.0% of cases had low amplitudes whereas among the controls 31.8% had low amplitudes. Thus, of the two audiological assessment methods, DPOAE captured the higher number of hearing loss indicating that for this study it best detected early noise induced hearing loss as compared to PTA – both conventional and EHFA. For the noise exposed block factory workers, there was a significantly higher prevalence of noise induced hearing loss by DPOAE measurement; and EHFA detected a higher prevalence of hearing loss than the conventional PTA.

Roughly half of the block factory workers had some knowledge of the effect of noise on their health and of HPDs. This did not however translate into them avoiding these effects with the use of HPDs as only few cases used them. The current study has also shown noise levels in block factories to exceed the permissible noise levels for both the traditional block factories and the high output factories.

The outcome of this study therefore agrees with the alternate hypothesis that DPOAEs records significantly higher hearing abnormality as compared to pure tone audiometry.

6.2 Recommendations

With these findings, it is recommended that hearing conservation programs should be extended to include cement block factory workers and should be enforced to improve their occupational safety and avoid the negative effects of excessive noise exposure on their health.

Worker's education on the effects of excessive noise exposure should be carried out and the need to use hearing protection devices should be emphasized. In addition, the need to have regular hearing screening should be carried out, with DPOAEs being done in the convenience of their factories to maximise participation.

Further investigation in occupational NIHL should be carried out in other informal industries generating excessive noise.

Longitudinal studies need to be carried out to follow the progression or other wise of the effects of noise exposure on the workers affected.

Personal listening device use among Ghanaians needs to be investigated to study its effect on the ear in this population.

REFERENCES

1. Browning GG. Clinical otology and audiology.2nd ed. London: Arnold;2001. Chapter 1, Hearing; p.1-4

2. Ologe FE, Akande TM, Olajide TG. Occupational noise exposure and sensorineural hearing loss among workers of a steel rolling mill. Eur Arch Otorhinolaryngol [Internet]. 2006 May 6[cited 2020 Feb 11]: 263, 618–621. https://doi.org/10.1007/s00405-006-0043-9

3. World Health Organization: Geneva. 2018. Addressing the rising prevalence of hearing loss. License: CC BY-NC-SA 3.0 IGO.

4. Nelson DL, Nelson RY, Concha-Barrientos M, Fingeruhut M. The Global Burden of Occupational Noise-induced Hearing Loss. Am J Ind Med 2005; 48:446-58.

5. Kitcher ED, Ocansey G, Tumpi DA. Early occupational hearing loss of workers in a stone crashing industry: our experience in a developing country. Noise and Health 2012; 14:68-71

6. Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, Stansfeld S. Auditory and non-auditory effect of noise on health. Lancet 2014April12;383(9925)

7. Ali SA. Industrial noise levels and annoyance in Egypt. Applied Aoustics,2010; 72(2011)221-225

8. McCullaugh MC, Raymond D, Kean MJ, Lusk SL. Prevalence of Hearing Loss and Adequacy of Self Report among Factory Workers. Noise Health 2011:13:340-7

9. Dube KJ, Ingale LT, Ingle ST. Hearing impairment Among Workers Exposed to Excessive Levels of Noise in Ginning Industries. Noise and Health September - October 2011;13(54)348-55

10. Kanji A, Khoza-Shangase K, Ntlhakana L. Noise induced hearing loss: what south African mine workers know. Int J Occup Saf Ergon, 2017.1-6 Pages 305-310.

11. Nada E, Ebraheem WM, Sheta S. Noise-induced hearing loss among workers in textile factory. Egyptian Journal of Otolaryngology.2014: Volume 30: Issue: 3 | Page: 243-248

12. Khoza-Shangase K, Ntlhakana L, Nelson G. Estimating miners at risk for occupational noise-induced hearing loss: A review of data from a South African platinum mine. S Afr J of Commun Disord. 2020 Feb 1;67(2):1-8. Available from: https://journals.co.za/doi/abs/10.4102/sajcd.v67i2.677

13. Mandeep C. Noise induced hearing loss in a steel rolling mill company in Nairobi, Kenya (Doctoral dissertation, University of Nairobi)

14. Omokhodion FO, Adeosun AA, Fajola AA. Hearing impairement among mill workers in small scale enterprises in south west Nigeria. Noise Health 2007; 9:75-7

15. Osibogun A, Igweze IA Adeniran L O. Noise induced hearing loss among textile workers in Lagos metropolis. Nigerian Postgraduate Medical Journal, 2000.

16. Kitcher ED, Ocansey G, Abaidoo B, Atule A. Occupational hearing loss of market mill workers in the city of Accra. Noise and Health 2014; 16(70): 183-188

17. Amedofu GK. Hearing impairment among workers in a surface gold mining company in Ghana. African Journal of Health and Science 2002; 9:91-7

18. Boating CA, Amedofu G K. Industrial noise pollution and its effect on the hearing capabilities of workers: a study from saw mills, printing presses and corn mills. African Journal of Health and Science, 2004;11:55-60

19. Amedofu GK, Brobby GW, Ocansey G. Occupational hearing loss among workers of a large gold-mining company in Ghana - 34th Annual Conference of the West African College of Surgeons. Jan 22nd -30th, 1998, Accra, Ghana.

20. Gyamfi CK, Amankwaa I, Owusu- Sekyere F, Boateng D. Noise exposure and hearing capabilities of quarry workers in ghana: a cross-sectional study. Journal of Environmental and Public Health. Volume 2016. Article ID7054276

21. Helfer TM, Canham-Chervak M, Canada S, Mitchener TA. Epidemiology of hearing impairment and noise-induced hearing injury among U.S. military personnel, 2003-2005. Am J Prev Med 2010; 38(1, Suppl.): S71–7.

22. Department of the Navy. Fiscal year 2011 annual occupational safety and health report to the Secretary of Labor. Retrieved December 2012 at w.public.navy.mil/navsafecen/…/OSH/…/OSHA_Rpt_FY11.pdf.

23. Olusanya BO, Neuman KJ, Saunders JE. World Health Organisation. 2014.The Global Burden of Disabling Hearing Impairment: A Call to Action. Bulletin of the World Health Organization.

24. Felipe J, Kumar U, Galope R. Middle-income transitions: trap or myth? J Asia Pac Econ. 2017 Jul 3;22(3):429-53.

25. Jonah CM, Sambu WC, May JD. A comparative analysis of socioeconomic inequities in stunting: a case of three middle-income African countries. Arch Public Health. 2018 Dec 1;76(1):77.

26. Moss T, Majerowicz S. No longer poor: Ghana's new income status and implications for graduation from IDA. Working Paper 300. July 2012. Center for Global Development.

27. Chi F, Chen X, Xhou J, Wang Y, Xang Q. Identification and gradation of wheel loader sources. 4th International Conference on Sustainable Energy and Environmental Engineering. (ICSEEE 2015)
28. Marriage JE, Solario-Corbetto M. Psycoacoustic audiometry. In: Watkinson JC, Clark RW, editors. Scott-Brown's Otorhinolaryngology, Head and Neck Surgery. 8th ed. London: CRC Press; 2018. p. 627-46.
29. Nunez DA, Qi L. Tests for hearing. In:Logan Turner's Diseases of the nose, throat and ear. Head and neck surgery. Hussain SM, editor. 11th ed. Florida:CRC Press;2016. p. 375-84.
30. Fausti SA, Erickson DA, Frey RH, Rappaport BZ, Schechter MA. (1981b) The effects of noise upon human hearing sensitivity from 8000 to 20 000 Hz. J Acoust Soc Am 69(5):1343–47.
31. Erickson DA, Fausti SA, Frey RH, Rappaport BZ. (1980) Effects of steady-state noise upon human hearing sensitivity from 8000 to 20 000 Hz. Am Ind Hyg Assoc J 41(6):427–32.
32. Rodríguez Valiente A, Roldán Fidalgo A, Villarreal I M, García Berrocal J R. Extended High-frequency Audiometry (9000–20000Hz). Usefulness in audiological diagnosis. Acta Otorrinolaringologica (English Edition) 2016; 67(1): 40–4. doi: 10.1016/j.otoeng.2015.02.001
33. Sulaiman AH, Husain R, Seluakumaran K. Evaluation of early hearing damage in personal listening device users using extended high-frequency audiometry and otoacoustic emissions. Eur Arch Otorhinolaryngol. 2013 Jun 28; 271: 1463–70 (2014). https://doi.org/10.1007/s00405-013-2612-z
34. Kumar P, Upadhyay P, Kumar A, Kumar S, Singh GB. Extended high frequency audiometry in users of personal listening devices. American Journal of Otolaryngology. 2017; 38(2): 163–167. doi: 10.1016/j.amjoto.2016.12.002
35. Bozzato A, Bozzato V, Hecker D, Mehrmann M, Guthardt Torres C, Schick B. Objective measurements for early diagnosis of noise induced hearing impairment using high frequency DPOAE up to 16kHz. C BY-NC-ND 4.0 · Laryngo-Rhino-Otol 2018; 97(S 02): S160-S161 DOI: 10.1055/s-0038-1640266
36. Feder K; Michaud D; McNamee J; Fitzpatrick E; Davies H; Leroux T. Prevalence of hazardous occupational noise exposure, hearing loss, and hearing protection usage among a representative sample of working Canadians. J Occup Environ Med: 2017 January;59 (1): 92-113. doi: 10.1097/JOM.0000000000000920

37. Yilmaz YF, Ilknur, AF, Akdogan O, Sari K, Savas, ZG†, Titiz A, et al. Sensorineural hearing loss after radiotherapy for head and neck tumors: A Prospective study of the effect of radiation. otology & neurotology.2008 Jun; 29(4): 461-3. doi: 10.1097/MAO.0b013e31816c7c9e

38. Seixas NS, Goldman B, Sheppard L, Neitzel R, Norton S, Kujawa SG. Prospective noise induced changes to hearing among construction industry apprentices. Occup Environ Med 2005; 62:309-17

39. Occupational Safety and Health Administration, United states Department of Labor [Internet]c2002; Hearing conservation 3074; c2002[2020 Mar 28]; [pp1-3]. Availablefrom: https://www.osha.gov/SLTC/noisehearingconservation/hearingprograms.html

40. Caldart A, Adriano C, Igor Terruel I, Martins R, Mocellin M. The prevalence of noise induced hearing loss among textile industry workers. Int Arch Otorhinolaryngology 2006; 10:10-4.

41. Dhingra PL. Diseases of ear, nose and throat. 4th ed. New Dehli: Elsevier; c2007. Chapter 1, Anatomy. p. 3-13

42. Gale J, Forge A. Anatomy of the cochlea and the vestibular system: Relating ultrastructure to function. In: Watkinson JC, Clark RW, editors. Scott-Brown's Otorhinolaryngology, Head and Neck Surgery. 8th ed. London: CRC Press; 2018. P.545-57.

43. Dhingra PL. Diseases of ear, nose and throat. 4th ed. New Dehli: Elsevier; c2007. Chapter 2, Peripheral receptors and physiology of auditory and vestibular systems. p. 14-9.

44. Dasgupta S, Maslin M. Physiology of hearing. In: Watkinson JC, Clark RW, editors. Scott-Brown's Otorhinolaryngology, Head and Neck Surgery. 8. 2018. 567–88 p.

45. McCombe A BDM. McCombe A, Baguley D M. Noise induced hearing loss and related conditions. In: Watkinson JC, Clark RW, editors. Scott-Brown's Otorhinolaryngology, Head and Neck Surgery. 8th ed. London: CRC Press; 2018. 701–8 p.

46. Brungart DS, Barrett ME, Schurman J, Sheffield B, Ramos L, Martorana R, et al. Relationship between subjective reports of temporary threshold shift and the prevalence of hearing problems in military personnel. journals.sagepub.com [Internet]. 2019 [cited 2022 May 14];23. Available from: https://journals.sagepub.com/doi/abs/10.1177/2331216519872601

47. Hussain T, Chou C, Zettner E, Torre P, Hans S, Gauer J, Markgraf M, Nguyen QT. Early indication of noise-induced hearing loss in young adult users of personal listening devices. Annals of Otology, Rhinology & Laryngology. 2018 Oct;127(10):703-9

48. Miao L, Zhang J, Yin L, Pu Y. Metabolomics Analysis Reveals Alterations in Cochlear Metabolic Profiling in Mice with Noise-Induced Hearing Loss. BioMed Research International. 2022 May 6;2022.

49. Burton JA, Mackey CA, Macdonald KS, Hackett TA, Ramachandran R. Changes in audiometric threshold and frequency selectivity correlate with cochlear histopathology in macaque monkeys with permanent noise-induced hearing loss. Elsevier [Internet]. 2020 [cited 2022 May 14]; 398:108082. Available from: https://www.sciencedirect.com/science/article/pii/S0378595520303531
50. Huh DA, Choi YH, Ji MS, Moon KW, Yoon SJ, Sohn JR. Comparison of Pure-Tone Average Methods for Estimation of Hearing Loss Caused by Environmental Exposure to Lead and Cadmium: Does the Pure-Tone Average Method Which Uses Low-Frequency Ranges Underestimate the Actual Hearing Loss Caused by Environmental Lead and Cadmium Exposure? Audiol Neurotol [Internet]. 2018 Jan 1 [cited 2022 Apr 23];23(5):259–69. Available from: https://www.karger.com/Article/FullText/494049
51. Arthur J. The effect of occupational noise levels on hearing among cement factory workers in Tema. 2016 [cited 2022 Jun 2]; Available from: http://ugspace.ug.edu.gh/handle/123456789/21174
52. Lie A, Skogstad M, Johnsen TS, Engdahl B, Tambs K. The prevalence of notched audiograms in a cross-sectional study of 12,055 railway workers. Ear and Hearing. 2015 May;36(3): e86.
53. Olusanya BO, Davis AC, Hoffman HJ. Hearing loss grades and the International classification of functioning, disability and health. Bull World Health Organ [Internet]. 2019 Oct 1 [cited 2022 Apr 23];97(10):725. Available from: /pmc/articles/PMC6796665/
54. Tanaka C, Taniguchi LD, Lew HL. Diagnosis and Rehabilitation of Hearing Disorders in the Elderly. Geriatr Rehabil. 2018 Jan 1;145–59.
55. Le Prell, CG. Spankovich, C; Lobariñas, E ; Griffiths, SK. Extended High-Frequency Thresholds in College Students: Effects of Music Player Use and Other Recreational Noise. Journal of the American Academy of Audiology, Volume 24, Number 8, September 2013, pp. 725-739(15) https://doi.org/10.3766/jaaa.24.8.9
56. Rodríguez Valiente A, Roldán Fidalgo A, Villarreal IM, García Berrocal JR. Extended high-frequency audiometry (9,000-20,000 Hz). Usefulness in audiological diagnosis. Acta Otorrinolaringol Esp [Internet]. 2016 Jan 1 [cited 2022 Apr 11];67(1):40–4. Available from: https://pubmed.ncbi.nlm.nih.gov/26025356
57. Fausti SA, Frey RH, Henry JA, Olson DJ, Schaffer HI. Early detection of ototoxicity using high-frequency, tone burst-evoked auditory brainstem responses. J Am Acad Audiol. 1992;3(6):397–404
58. Konrad-Martin D, Gordon JS, Reavis KM, Wilmington DJ, Helt WJ, Fausti SA. Audiological Monitoring of Patients Receiving Ototoxic Drugs. Perspect Hear Hear Disord Res Diagnostics

[Internet]. 2005 Sep 1;9(1):17. Available from: http://sig6perspectives.pubs.asha.org/article.aspx?doi=10.1044/hhd9.1.17

59. Tange, R.A., Dreschler, W.A. & van der Hulst, R.J.A.M. The importance of high-tone audiometry in monitoring for ototoxicity. Arch Otorhinolaryngol 242, 77–81 (1985). https://doi.org/10.1007/BF00464411

60. Fausti SA, Schechter MA, Rappaport BZ, Frey RH, Mass RE. Early detection of cisplatin ototoxicity selected case reports. Cancer. 1984 Jan 15;53(2):224-31

61. Laffoon SM, Stewart M, Zheng Y, Meinke D K. Conventional audiometry, extended high-frequency audiometry, and DPOAEs in youth recreational firearm users. Int J Audiol.2019 Jan 8;58(1)1–9. doi:10.1080/14992027.2018.1536833

62. Alabdulwahhab BM, Alduraiby RI, Ahmed MA, Albatli LI, Alhumain MS, Softah NA, et al. ARTICLE Hearing loss and its association with occupational noise exposure among Saudi dentists: a cross-sectional study. Nat Publ Gr [Internet]. 2016;2. Available from: www.nature.com/bdjopen

63. Attias J, Horovitz G, El-Hatib N, Nageris B. Detection and clinical diagnosis of noise-induced hearing loss by otoacoustic emissions. Noise Health 2001; 3:19-31

64. Oeken J, Lenk A, Friedrich Bootz. Influence of age and presbyacusis on DPOAE. Journal Acta Oto-Laryngologica. 2000:120(3):396-403 | Published online: 08 Jul 2009. https://doi.org/10.1080/000164800750000630

65. Hall AJ, Lutman ME. Methods for early identification of noise-induced hearing loss. Audiology. 1999.38(5). 277-80. DOI: 10.3109/00206099909073035 Published online: 07 Jul 2009

66. Prieve BA Thomas L, Long G, Talmadge C. Observations of distortion product otoacoustic emission components in adults with hearing loss. Ear and hearing:2020May/June;41 (3):652-62.

67. Stamper GC, Johnson TA. Auditory function in normal- hearing, noise-exposed human ears. Ear and Hearing (2015),36(2), 172-184. doi:10.1097/aud.0000000000000107

68. Kujawa SG, Liberman MC. Translating animal modules to human therapeutics in noise induced and age-related hearing loss. Hearing Research. Vol 377, June 2019.p.44-52 https://doi.org/10.1016/j.heares.2019.03.003

69. Lin HW, Furman AC, Kujawa SG, Liberman M. Primary neural degeneration in the guinea pig cochlea after reversible noise-induced threshold shift. J Assoc Res Otolaryngol. 2011; 12:605–16

70. Wooles, N., Mulheran, M., Bray, P., Brewster, M., & Banerjee, A. R. (2015). Comparison of distortion product otoacoustic emissions and pure tone audiometry in occupational screening for auditory deficit due to noise exposure. J Laryngol Otol, 129(12), 1174–1181. doi:10.1017/s0022215115002790

71. Marshall L, Lapsley Miller JA, Heller LM, Wolgemuth KS, Hughes LM, Smith SD, & Kopke RD. (2009). Detecting incipient inner-ear damage from impulse noise with otoacoustic emissions. The Journal of the Acoustical Society of America, 125(2), 995–1013. doi:10.1121/1.3050304

72. Medina-Garin DR, MD; Dia A; Gabriel Bedubourg G; Deparis X; Berger F; Michel R. Acute acoustic trauma in the french armed forces during 2007–2014. Noise and Health. 2, 32016 Nov-Dec; 18(85): 297–302. doi: 10.4103/1463-1741.195802 PMCID: PMC5227009 PMID: 27991460

73. Olaosun, AO, Ogundiran O, Tobih J E. Health Hazards of Noise: A Review Article. Research Journal of Medical Sciences2009.3(3):115-22.

74. Le, T N; Straatman, L V; Lea J; Westerberg B. Current insights in noise-induced hearing loss: a literature review of the underlying mechanism, pathophysiology, asymmetry, and management options. Journal of Otolaryngology - Head & Neck Surgery2017: 46: Article number: 41.

75. Mathers C, Smith A, Concha M. Global burden of hearing loss in the year 2000. Global burden of Disease. 2000;18(4):1-30

76. Goulios H, Robertson D. Noise-induced cochlear damage assessed using electrophysiological and morphological criteria: an examination of the equal energy principle. Hear Res. 1983 Sep;3(11):327-41. Available from: https://doi.org/10.1016/0378-5955(83)90065-5

77. Yong JS ern, Wang DY. Impact of noise on hearing in the military. Mil Med Res. 2015 Feb 25;2(1).

78. Choi CH. Mechanisms and treatment of blast induced hearing loss. Korean Journ of Audiol. 2012 Dec;16(3):103.

79. Alam, M., Wahab, M., Rahman, M., Asaduzzaman, A., Al-Azad, M., Karim, M., & Sultana, S. (2014). Prevalence of hearing loss in military aviators: The audiometry and risk factors analysis. Journal of Armed Forces Medical College, Bangladesh, 9(1), 19-24. https://doi.org/10.3329/jafmc.v9i1.18721

80. Win KN, Balalla NB, Lwin ZM, Lai A. Noise-induced hearing loss in the police force. Safety and Health at Work.2015 Jun;6(2):134-8

81. Ingle ST, Pachpande BG, Wagh ND, Attrade SB. Noise exposure and hearing loss among the traffic policemen working at busy street of Jalgoan Urban Centre. Transport Res Part D 2005; 10:69-75
82. Lesage FX, Jovenin N, Deschamps F, Vincent S. Noise induced hearing loss in French police officers. J Occup Med (London) 2009; 59:483-6
83. van der Molen HF, de Vries SC, Stocks SJ, et al. Incidence rates of occupational diseases in the Dutch construction sector, 2010–2014.Occup Environ Med 2016;73:350-352
84. Shukla A, Lal P. Hearing loss and morbidity among construction site workers in National Capital Region of Delhi, India. Paper presented at: 12th ICBEN Congress on Noise as a Public Health Problem; 2017 Jun,18-22; Zurich.
85. l-Dayyeni W, Qin J. Comparison of New Metrics for Assessment of Risks of Occupational Noise. Journal of Applied Sciences and Arts. 2017 Dec;1(3):4.
86. Foster JR, Hall DA, Summerfield QA, Palmer AR, Bowtell RW. Sound-Level measurements and calculations of safe noise dosage during EPI at 3T. J Magn Reson Imaging.2000;12:157-63
87. Bolaji BO, Olanipekun MU, Adekunle AA, Adeleke AE. An analysis of noise and its environmental burden on the example of Nigerian manufacturing companies. J Clean Prod [Internet]2018 Jan 20[cited 2020 Apr 18th]; 172:1800-1806.Available from: https://doi.org/10.1016/j.jclepro.2017.12.007
88. Huang FJ, Hsieh CJ, Young CH, Chung SH, Tseng CC, Yiin LM. The assessment of exposure to occupational noise and hearing loss for stoneworkers in Taiwan. Noise Health[Internet]. 2018 Jul-Aug [cited2020 Apr 25th]; 20(95): 146–51. Available from: doi: 10.4103/nah.NAH_45_17
89. Ylikoski ME. Prolonged exposure to gunfire noise among professional soldiers. Scandinavian journal of work, environment & health. 1994 Apr 1:87-92
90. Heupa AB, Gonçalves CG de O, Coifman H. Effects of impact noise on the hearing of military personnel. Braz J Otorhinolaryngol [Internet]: 2011, Nov-Dec [cited 2020, May 4th];77(6):747-53. https://doi.org/10.1590/S1808-86942011000600011
91. Toppila E, Koskinen H, Pyykkö I. Hearing loss among classical-orchestra musicians. Noise Health [serial online] 2011 [cited 2020 Jun 15]; 13:45-50. Available from: http://www.noiseandhealth.org/text.asp?2011/13/50/45/74001
92. Emmerich E., Rudel L. & Richter F. 2008. Is the audiologic status of professional musicians a reflection of the noise exposure in classical orchestral music? Eur Arch Otorhinolaryngol

[Internet]2008, Jul; [cited 2020, Mar 30th] 265, 753–758. Available from: https://doi.org/10.1007/s00405-007-0538-z

93. Laitinen HM, Toppila EM, Olkinuora PS, Kuisma K. Sound exposure among the Finnish National Opera personnel. Appl Occup Environ Hyg. 2003 Mar 1;18(3):177–82.

94. Niu X. & Canlon B. 2002. Protective mechanism of sound conditioning. Adv Oto-Rhino-Laryngology, 59, 96–105.

95. Miyakita T, Hellström PA, Frimansson E, Axelsson A. Effect of low-level acoustic stimulation on temporary threshold shift in young humans. Hear Res.1992; 60:149–55.

96. Kazkayasi M., Yetiser S.& Ozcelik S. 2006 Effect of musical training on musical perception and hearing sensitivity: Conventional and high-frequency audiometric comparison. J Otolaryngol, 35(5), 343–348

97. Zhao F, Manchaiah VKC, French D, Price SM. Music exposure and hearing disorders: An overview. Int J of Audiol [Internet] 2010, Dec 10th [cited 2020, June,14];49(1):54–64. https://www.tandfonline.com/doi/abs/10.3109/14992020903202520
https://doi.org/10.3109/14992020903202520.

98. Suter, A. H. (2002). Construction noise: exposure, effects, and the potential for remediation; A review and analysis. AIHA Journal, 63(6), 768–789. doi:10.1080/1542811020898476

99. Fernández MD, Quintana S, Chavarría N, Ballesteros JA. Noise exposure of workers of the construction sector. Appl Acoust. 2009 May;70(5):753–60.

100. Berglund B, Lindvall T. New WHO Guidelines for Community Noise (2000). Available from: https://journals.sagepub.com/doi/abs/10.1260/0957456001497535

101. King RP, Davis JR. Community noise: Health effects and management. Int J Hyg. Environ Health [Internet] 2003. [cited 2020 Apr 18th], 206(2), 123–31.

102. Marron KH, Marchiondo K, Stephenson S, Wagner S, Cramer C, Wharton T, Hughes M, Sproat B, Alessio H. College students' personal listening device usage and knowledge, Int J Audiol. 2015 54:6, 384-390,
DOI: 10.3109/14992027.2014.986691

103. Omokhodion FO, Adeosun AA, Fajola AA. Hearing impairment among mill workers in small scale enterprises in southwest Nigeria. Noise and Health. 2007 Jul 1;9(36):75.

104. Masterson EA, Tak S, Themann CL, Wall DK, Groenewold MR, Deddens JA, et al. Prevalence of hearing loss in the United States by industry. Am J Ind Med. 2013 Jun;56(6):670–81

105. Neghab M, Maddahi M, Rajaeefard A. Hearing impairment and hypertension associated with long term occupational exposure to noise. IRCMJ. 2009; 11(2): 160-5

106. Amedofu GK. Effectiveness of hearing conservation program at a large surface gold mining company in Ghana. Afr J Health Sci. 2007; 14:49-53

107. Moroe NF. Occupational noise-induced hearing loss in South African large-scale mines: exploring hearing conservation programmes as complex interventions embedded in a realist approach. Int J Occup Saf and Ergon.2018 Aug 23rd [cited 2020 Mar 27]. Available from: https://www.tandfonline.com/doi/full/10.1080/10803548.2018.1498183 DOI: 10.1080/10803548.2018.1498183

108. Suter AH. Engineering controls for occupational noise exposure – the best way to save hearing. Sound and Vibration. 2012 p24-30. pdfs.semanticscholar.org

109. Tantranont K, Codchanak, N. Predictors of hearing protection use among industrial workers. Workplace Health & Safety,2017. 65 (8): 365–71. doi:10.1177/2165079917693019. ISSN 2165-0799. PMID 28422611

110. Smith PS, Monaco BA, Lusk SL. Attitudes toward use of hearing protection devices and effects of an intervention on fit-testing results. Work Heal Saf. 2014 Dec 1;62(12):491–9.

111. Noise & Hearing Loss Prevention | NIOSH | CDC [Internet]. [cited 2022 Apr 26]. Available from: https://www.cdc.gov/niosh/topics/noise/default.html

112. Hansia MR, Dickinson D. Hearing protection device usage at a South African gold mine. Occupational Medicine [Internet]. 2010 Jan 1[cited 2020 June, 23]; 60(1). 72–74. https://doi.org/10.1093/occmed/kqp114

113. Ologe FE, Akande TM, Olajide TG. Noise exposure, awareness, attitudes and use of hearing protection in a steel rolling mill in Nigeria. Occup Med (Chic Ill) [Internet]. 2005 Sep 1 [cited 2022 Jun 7];55(6):487–9. Available from: https://academic.oup.com/occmed/article/55/6/487/1415716

114. Cheung L, Baguley DM, McCombe A. Age related sensorineural hearing impairment. In: Watkinson JC, Clark RW, editors. Scott-Brown's Otorhinolaryngology, Head and Neck Surgery. 8th ed. London: CRC Press; 2018. P. 693-4

115. KBTH. 2016 Annual Report, Korle Bu Teaching Hospital. 2016.

116. Singh p. 2012 sample size for experimental studies - Google Scholar [Internet]. [cited 2022 Jun 19]. Available from: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=singh+p.+2012+sample+size+for+e

xperimental+studies&btnG=
117. Mehrparvar AH, Mirmohammadi SJ, Davari MH, Mostaghaci M, Mollasadeghi A, Bahaloo M, Hashemi SH. Conventional audiometry, extended high-frequency audiometry, and DPOAE for early diagnosis of NIHL. Iranian Red Crescent Medical Journal. 2014 Jan;16(1).
118. Ali A, Garandawa HI, Nwawolo CC, Somefun OO. Noise-induced hearing loss at cement company, Nigeria. Online J Med Med Sci Res. 2012 Jun;1:49-54
119. Aliyu N, Iseh KR, Mohammed A, Yikawe SS, Inoh MI, Manya C. Hearing loss among cement factory workers in Northwest Nigeria. Indian Journal of Otology. 2020 Jul 1;26(3):173
120. Nyarubeli IP, Tungu AM, Moen BE, Bråtveit M. Prevalence of noise-induced hearing loss among Tanzanian iron and steel workers: A cross-sectional study. International Journal of Environmental Research and Public Health. 2019 Apr;16(8):1367.
121. Omer HA. Noise exposure, awareness, practice and noise annoyance among steel workers in United Arab Emirates. openpublichealthjournal.com [Internet]. 2012 [cited 2022 Jun 7]; Available from: https://openpublichealthjournal.com/volume/5/page/28/fulltext/
122. Annan JS, Addai EK, Tulashie SK. A call for action to improve occupational health and safety in Ghana and a critical look at the existing legal requirement and legislation. Safety and health at work. 2015 Jun 1;6(2):146-50.
123. McBride DI, Williams S. Audiometric notch as a sign of noise induced hearing loss. Occup Environ Med [Internet]. 2001 Jan 1 [cited 2022 Jun 13];58(1):46–51. Available from: https://oem.bmj.com/content/58/1/46
124. Osei-Lah V, Yeoh LH. High frequency audiometric notch: An outpatient clinic survey. Int J Audiol. 2010;49(2):95–8
125. Mehrparvar AH, Mirmohammadi SJ, Ghoreyshi A, Mollasadeghi A, Loukzadeh Z. High-frequency audiometry: a means for early diagnosis of noise-induced hearing loss. Noise and Health. 2011 Sep 1;13(55):402.
126. Türkkahraman S, Gök U, Karlidağ T, Keleş E, Oztürk A. Findings of standard and high-frequency audiometry in workers exposed to occupational noise for long durations. Kulak burun bogaz ihtisas dergisi: KBB= Journal of ear, nose, and throat. 2003 Apr 1;10(4):137-42.
127. Han J, Li F, Zhao C, Zhang Z, Ni D. Study on distortion product otoacoustic emissions and expanded high frequency audiometry in noise exposure workers. Lin Chuang er bi yan hou ke za zhi= Journal of Clinical Otorhinolaryngology. 2003 Jan 1;17(1):16-9.

APPENDICES

1.0: Questionnaire

3. QUESTIONNAIRE

Date: …………………….   **ID No.** ………………

1. Gender: Male [ ]   Female [ ]
2. Age (years)   ……………….
3. Highest level of education

   Primary [ ]   JHS [ ]   SHS [ ]   Tertiary [ ]   None [ ]
4. Occupation   …………………………………………
5. Job description ………………………………………
6. Duration of service ………………………………… (yrs.).
7. Hours of work per day ………………………………
8. Total hours of work per week ………………………
9. Days of rest per week ………………………………
10. Do you have any of these chronic diseases:

    a) Diabetes   [ ]
    b) Hypertension   [ ]
    c) Sickle Cell Disease   [ ]
    d) Others ……………….   [ ]
    e) None   [ ]

11. Do you drink alcohol? Yes [ ]   No [ ]
12. Do you smoke cigarettes? Yes [ ]   No [ ]
13. Do you have any hearing loss? Yes [ ]   No [ ]
14. If yes, for how long? ……………………………..
15. Do you have tinnitus (*ringing sound in the ear*)? Yes [ ]   No [ ]
16. If yes, for how long? ……………………………..
17. Do you know about the effects of noise on your health? Yes [ ]   No [ ]
18. Which of these health effects do you know of?

    a. Hearing loss [ ]
    b. Tinnitus   [ ]
    c. Annoyance   [ ]
    d. Increased risk of workplace injury   [ ]

19. Do you think you are exposed to too much noise at work? Yes [ ] No [ ]

20. Do you know of hearing protection devices? Yes [ ] No [ ]

21. Which of these hearing protection devices do you know of?

   a. Ear muffs
   b. Ear plugs
   c. Semi-insert devices
   d. Electronic hearing protection devices
   e. Others

22. Do you use any hearing protection device? Yes [ ] No [ ]

23. If no, why not:

   a. Cost [ ]
   b. Availability [ ]
   c. Discomfort with use [ ]
   d. Makes communication at work difficult [ ]
   e. Others [ ]

24. If yes, which of these hearing protection devices do you use?

   a) Ear muffs [ ]
   b) Ear plugs [ ]
   c) Semi-insert devices [ ]
   d) Electronic hearing protection devices [ ]
   e) Others

25. Do you think you need hearing protection devices? Yes [ ] No [ ]

Ear Muff

Ear Plugs

Semi -insert device

2.0 Hearing Assessment Report Form

OCCUPATIONAL NOISE EXPOSURE AND HEARING LOSS AMONG CEMENT BLOCK FACTORY WORKERS: A COMPARISON OF TWO ASSESSMENT METHODS

ID……….

AUDIO ASSESSMENT REPORTS

1. TYMPANOMETRY

NORMAL VALUES	RIGHT EAR	LEFT EAR
ECV (0.2-2.0ml)		
PEAK (0.2-2.0ml) COMPLIANCE		
PEAK PRESSURE (-150-+100daPa)		
TYPE (A, B, C)		

2. PURE TONE AUDIOMETRY

	.25	.5	1	2	3	4	6	8	9	11.2	12.5	14	16
RIGHT													
LEFT													

3. DPOAE ($f_2/f_1 = 1.22$)

f_2 / $DP_{65/55}$	2	3	4	6	8
Right					
Left					

3.0 Participant Information Sheet

PARTICIPANT INFORMATION SHEET

Title of Research Project: Occupational Noise Exposure Among Cement Block Factory Workers: A Comparison of Two Methods of Assessment

Principal Investigator: Dr Grace Naa Agowa Amoo-Quaye; Otolaryngology Unit, Department of Surgery, Korle Bu Teaching Hospital. Post Office Box 77, Korle Bu. Tel: 0205196611

General information about the Research

This research is in partial fulfillment of my dissertation leading to the award of Fellow of the Ghana College of Physicians and Surgeons - Otolaryngology. It aims to study the effects of noise on hearing and its ability to cause hearing loss among block factory workers. It will also compare the ability of one method of assessment to be able to identify hearing loss among this population earlier than the other.

What will be required from each participant will be to answer a questionnaire that will last for about 10-20 minutes and then following that, have a hearing assessment test in two different ways, lasting about 1hour 30 minutes.

Possible Risks and Discomforts

There are no known risks or discomforts associated with participation in this study.

Confidentiality

Your name will not appear in any part of this research report or any future publications. Every data obtained within the course of this research would be securely kept under lock and key and would be shredded a year after graduation.

Compensation

Your participation in this project is voluntary, and you will not be paid for doing so.

KORLE BU TEACHING HOSPITAL
14 JAN 2021
I. R. B

Additional Cost

No cost will be incurred by participants. Participants will be conveyed to and from the hearing assessment center by transportation arrangements made by the principal investigator.

Voluntary Participation and the Right to Leave the Research

Your participation is voluntary and you are free to withdraw at any time without giving any reason and without any negative consequences for you.

Additional Information and Rights as Participants

Any questions you have regarding the research and your rights as a participant may be answered by contacting the principal investigator, Dr Grace Amoo-Quaye.

You may also contact the Institutional Review Board of Korle Bu Teaching Hospital on 0302666766 or e-mail: rdo@kbth.gov.gh, or Ethical and Protocol Review Committee of the College of Health Sciences, University of Ghana, Legon on 030266103 / 0302940528 or e-mail at eprc@chs.edu.gh.

2. STATEMENT OF CONSENT FORM/VOLUNTARY AGREEMENT

I, ……………………………………………………………., willingly agree to participate in this study being conducted by Dr Grace Naa Agowa Amoo-Quaye of the Ear, Nose and Throat Unit of the Department of Surgery of the Korle Bu Teaching Hospital, Accra.

I understand that I can withdraw from the study at any time. Participation in this study will not result in any potential harm to me. Findings of this study will be kept confidential and would be made available to me upon request. I may also ask any question I have now or later. I have been informed that this proposal is reviewed, approved and granted ethical clearance by the Ethics and Protocol Review Committees of the College of Health Sciences and Korle-Bu Teaching Hospital. These committees are responsible for protecting research participants from harm. By signing this form, I am agreeing to take part in this research study.

I have read the foregoing information, or it has been translated to me in a language I understand. I have had the opportunity to ask questions about it and answers given me are to my satisfaction. I consent voluntarily to participate in this study.

………………………………………………………………… ……………………………………….. ……………………..

Name of Principal Investigator Signature Date

………………………………............................... ………………………………………… ……………………

Name of Participant Signature Date

If participant cannot read or write English, signed by the investigator…………………………

In the presence of an independent witness who can read and write English …………………

(Where possible this person should be selected by the participant).

Thumbprint (for the participant who cannot read or write):

Date………………………… Place/ Study Site……………………………………………...

Signature (researcher): ....

Place: ....

Date: ....

Questions can be addressed to the Principal Investigator (0205 1966 11. amooquaye@. yahoo.com). Additional questions or problems concerning your rights as a research participant should be addressed to:

The Chairman,

Ethics and Protocol Review Committee,

College of Health Sciences and Korle-Bu Teaching Hospital,

Korle-Bu, Accra, Ghana.

KORLE BU TEACHING HOSPITAL
14 JAN 2021
I. R. B

4.0 KBTH IRB Approval Letter

In case of reply the number
And the date of this
Letter should be quoted

My Ref. No. KBTH/MD/G3/21
Your Ref. No...........................

KORLE BU TEACHING HOSPITAL
P. O. BOX KB 77,
KORLE BU, ACCRA.

Tel: +233 302 667759/673034-6
Fax: +233 302 667759
Email: Info@kbth.gov.gh
pr@kbth.gov.gh
Website: www.kbth.gov.gh

14th January, 2021

DR GRACE NAA AGOWA AMOO-QUAYE
OTOLARYNGOLOGY,EAR, NOSE AND THROAT UNIT
DEPARTMENT OF SURGERY
KORLE BU

OCCUPATIONAL NOISE EXPOSURE AND HEARING LOSS AMONG CEMENT BLOCK FACTORY WORKERS: A COMPARISON OF TWO ASSESSMENT METHODS

KBTH-IRB /000177/2020

Investigator: Dr Grace Naa Agowa Amoo-Quaye

The Korle Bu Teaching Hospital Institutional Review Board (KBTH IRB) reviewed and granted approval to the study entitled: "Occupational Noise Exposure and Hearing Loss among Cement Block Factory Workers: A Comparison of Two Assessment Methods"

Please note that the Board requires you to submit a final review report on completion of this study to the KBTH-IRB.

Kindly, note that, any modification/amendment to the approved study protocol without approval from KBTH-IRB renders this certificate invalid.

Please report all serious adverse events related to this study to KBTH-IRB within seven days verbally and fourteen days in writing.

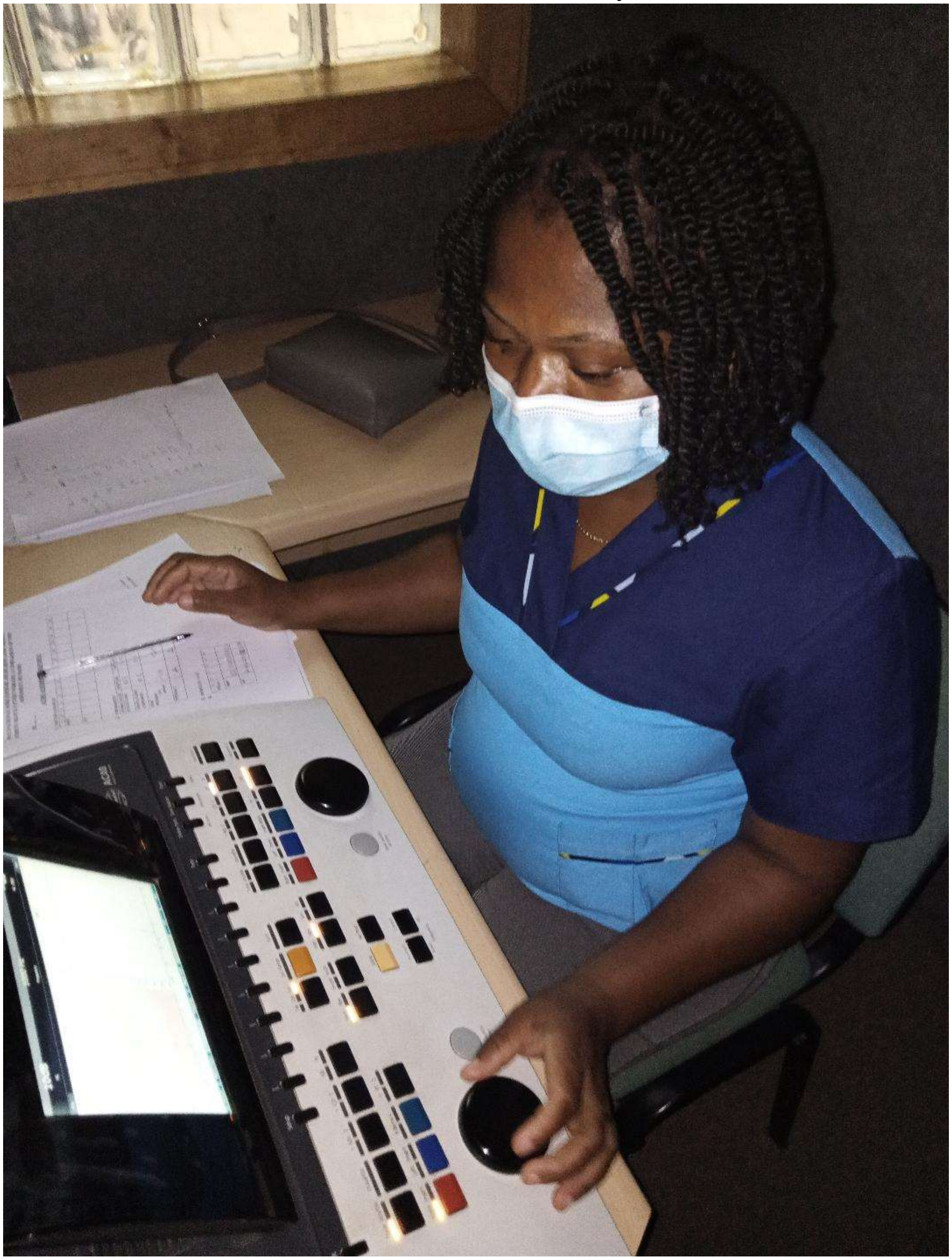
This IRB approval is valid till 30th December, 2021. You are to submit annual report for continuing review.

Sincere regards,

DR. DANIEL ANKRAH
VICE CHAIR (KBTH-IRB)
FOR: CHAIR (KBTH-IRB

Cc: The Chief Executive Officer, KBTH
The Director of Medical Affairs, KBTH

5.0 Puretone Audiometry



6.0 Sentiero DPOAE Device

7.0 Locally-manufactured cement block making machine

8.0 High output cement block making machine

9.0 Noise level measurement