Measurement of distortion product otoacoustic emissions in South African gold miners at risk for noise-induced hearing loss

A thesis submitted to
the discipline of Speech Pathology and Audiology
School of Human and Community Development
Faculty of Humanities
University of the Witwatersrand

In fulfilment of the requirements
for a Doctor of Philosophy

by Anita Lynne Edwards

Johannesburg, October, 2009

I declare that this thesis project is my own, unaided work. It is submitted for the degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at this or any other university.

Anita Lynne Edwards

21st day of October 2009.

Acknowledgements

"Delight yourself in the Lord and He will give you the desires of your heart"
Ps 37.4

Prof. Claire Penn (University of the Witwatersrand) for your insightful guidance and sharing your research expertise. Thank you for your time, patience and energy in helping me attain this life goal.

Dr. Jackie Clark (University of Texas at Dallas) for sharing your expertise and your gentle encouragement.

Prof. Steffens (University of Johannesburg) for your clear guidance and understanding of what I wanted to achieve and for directing me in the right direction in the statistical analysis.

Peter Fridjhon for your guidance in the statistical analysis.

The host mine staff in the audiology department for the use of the database and for the co-operation in this study.

CSIR for funding the project.

Bruce, my wonderful husband, who has encouraged me and shared my joy in achieving my goal.

My children, parents, family and friends for the encouragement and interest taken in the project.

My sister, Linda, for the many hours of patience and expertise with the initial data management that made the information useful for the project.

Dedicated to those who have lost their hearing in the workplace.

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List of Abbreviations

ABR	Auditory Brainstem Response
ANSI	American National Standards Institute
ASHA	American Speech and Hearing Association
COIDA	Compensation for Occupational Injuries and Diseases Act
dB	decibels
dBA	A-weighted decibels
dB HL	decibels Hearing level
dB SPL	decibels Sound pressure level
DME	Department of Minerals and Energy
DPOAE	Distortion product otoacoustic emission
EU	European Union
GSI	Grason Stadler Incorporated
HCP	Hearing Conservation Programme
HPD	Hearing protection devices
HSE	Health and Safety Executive
ICF	International Classification Framework
ISO	International Standards Organisation
MHSA	Mine Health and Safety Act
MHSC	Mine Health and Safety Council
NIHL	Noise Induced hearing loss
NIOSH	National Institute of Safety and Health
ODMWA	Occupational Diseases for Mineworkers Act
OEL	Occupational Exposure Level
OHC	Outer hair cells
OHSA	Occupational Health and Safety Act
OHS	Occupational Health and Safety
PEL	Permissible Exposure Level
PLH	Percentage Loss of Hearing
PTA	Pure-tone average

REL	Recommended Exposure Level
RMA	Rand Mutual Assurance
SANS	South African national Standards
SRT	Speech recognition threshold
TES	Temporary Emission Shift
TTS	Temporary Threshold Shift
TWA8h	Time Weighted Average for 8 hours
WHO	World Health Organisation

Abstract

Background

The noise-exposed population in the mining industry in South Africa poses unique problems to the occupational audiologist working in this environment, due to the broad linguistic and cultural diversity in the audiology and mining environment. Unfortunately, the problems are also exacerbated by a high incidence of pseudohypacusis within this population who are incentivised by compensation for NIHL. A solution to these specific problems would be the reliable and valid use of an objective test of function such as the DPOAE. The rationale for the study therefore was to extend the body of knowledge about the use of DPOAEs in the noise-exposed mining population.

Methodology

The current study was divided into two phases: phase one's objectives entailed the investigation of the characteristics of DPOAEs in a noise-exposed mining population; phase two aimed to develop a multivariate regression model that would facilitate the prediction of the hearing threshold levels from the DPOAE levels in this population.

Objectives

The objectives in phase one of the study were to investigate the bivariate correlations between DPOAE levels and air-conduction hearing threshold levels in noise-exposed gold miners, for the three stimulus procedures. The study also aimed to investigate the bivariate correlations between various pure-tone averages (PTA) and the DPOAE averages of f_2 frequencies closest to those pure-tone frequencies. Similarly, the Speech Recognition Thresholds (SRT) were correlated with DPOAE averages of f_2 frequencies closest to the PTA.

The study further aimed to investigate the characteristics of DPOAEs in noise-exposed gold miners by comparing the average DPOAE levels for different age category groups, different ethnic groups and for different occupation types. Finally, phase one aimed to describe the characteristics of emission level and noise floor differences (DP-NF) in a DPOAE database of a noise-exposed gold mining population.

Phase two of the study had the objective of developing a multivariate prediction model using stepwise regression analysis to identify which of the DPOAE frequencies produced the best prediction of the audiogram frequencies when multivariate inputs were used for each stimulus procedure. The objective was also to evaluate the use of the predicted audiograms' calculated percentage loss of hearing (PLH) with that of the actual PLH.

This retrospective record review used an audiological database from a mine in the North West province of South Africa that contained 4800 records. The required sample size to be representative of the population was statistically determined. The records were randomly selected resulting a sample size for the FB2-S group of 161, for the FB1-S group of 177 and the FB1-S group of 155 respectively. The hearing loss characteristics in the samples ranged from normal to profound losses with the majority being mild to moderate hearing losses.

Results

The findings of phase one showed negative correlations ranging from -0.327 to -0.573 for Frequency Band 1- Replicated (FB1-R) between DPOAE levels and air conduction hearing threshold levels. Similarly, Frequency Band 1-Single (FB1-S) and Frequency Band 2-Single (FB2-S) also showed negative correlations (ranging from -0.203 to -0.609 and -0.274 to -0.738 respectively). These correlation strengths have been confirmed previously by other published studies.

Correlations between groups of frequencies on an audiogram and averaged match groups of DPOAE frequencies by intensity levels, both for PTA and SRT, ranged between -0.323 and -0.661. No statistically significant differences were found between the DPOAE measurements and ethnic groups of African and Caucasian (Sample size of 175 for FB1-S, 137 for FB1-R and 161 for FB2-S). No differences were found between the DPOAE levels and the occupation types of mining team members, stopers and drillers. There was, however, a relational finding of a progressive decrement of DPOAE intensity levels by decade of age increase (Sample size of 37 for FB1-S, 45 for FB1-R and 155 for FB2-S).

Mean DP levels in this population ranged from 1.5 to -14 dB SPL, and mean NF levels in the sample ranged from 0.1 to -16.8 dB SPL with the mean DP-NF difference ranges form 0.4 to 9.3 dBSPL. More than 60% of the data collected resulted in a DP-NF of less than 10 dB SPL.

The simple correlation relationship between hearing threshold levels and DPOAEs did not sufficiently explain the variance within the sample and due to the fact that a number of the independent variables in the sample were highly correlated, there was a call to use a method that allows for multicolinearity (i.e. stepwise regression analysis) in order to develop a prediction model. Consequently, phase two of the study was able to compare actual air-conduction hearing threshold levels with those calculated with the prediction model, and then calculate predicted percentage loss of hearing (PLH) with actual PLH found in the noise-exposed gold miners.

In phase two, with the use of the predictive models, the predicted hearing threshold levels were found to differ from the actual thresholds by no more than 7dB HL across all frequencies (average of 5 dB HL for FB1-R, 2 dB HL for FB1-S and 3 dB HL for FB2-S). The differences for each audiogram frequency between the actual and the predicted thresholds are represented on scatter plots in phase two of the thesis. The PLH of the predicted audiograms was calculated using the weighted

tables prescribed by the Compensation for Occupational Diseases and Injuries Act (COIDA). A comparison of the predicted PLH with the actual PLH indicated that the predicted PLH ranged between minus 1.3% PLH and plus 6.7% PLH of the actual PLH.

Results of the study are discussed with regards to the clinical implications, and the implications for training occupational audiologists in South Africa. The results of this study will improve and inform practice in the mining environment and in the field of compensation for NIHL. By developing a reliable prediction tool which is implemented on an objective test proven to document the extent of damage incurred from noise-exposure, a clinician will gain greater confidence in an accurate diagnosis, thereby further safeguarding a vulnerable population. The results from this study are highly relevant to the mining industry and will add value to the industrial development of South Africa by informing the policy on hearing conservation and compensation, thereby increasing the awareness of the need for improved occupational health and safety conditions and sustainable development in the mining industry.

Key words: DPOAE; NIHL compensation; prediction model for hearing threshold levels; characteristics of DPOAE; NIHL in mining.